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AND
CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

OCTOBER 1960 **VOL. LV. NO. 10**

FIFTY-FIFTH YEAR OF PUBLICATION

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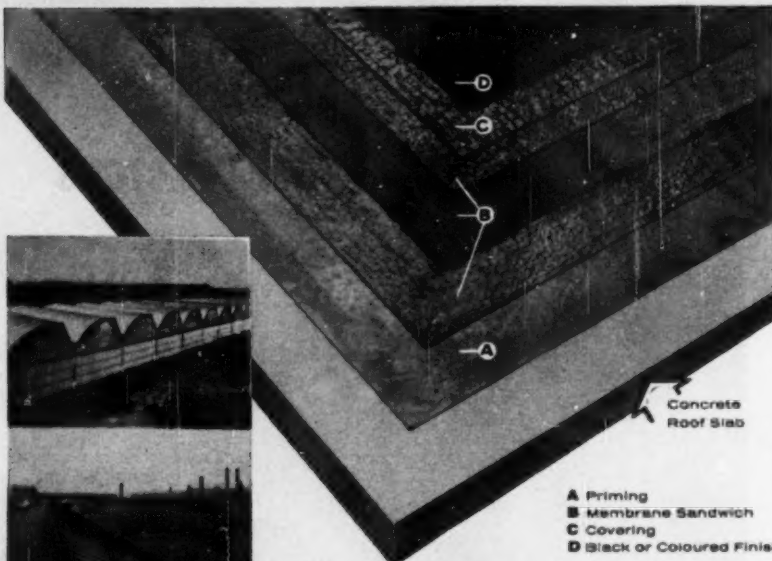
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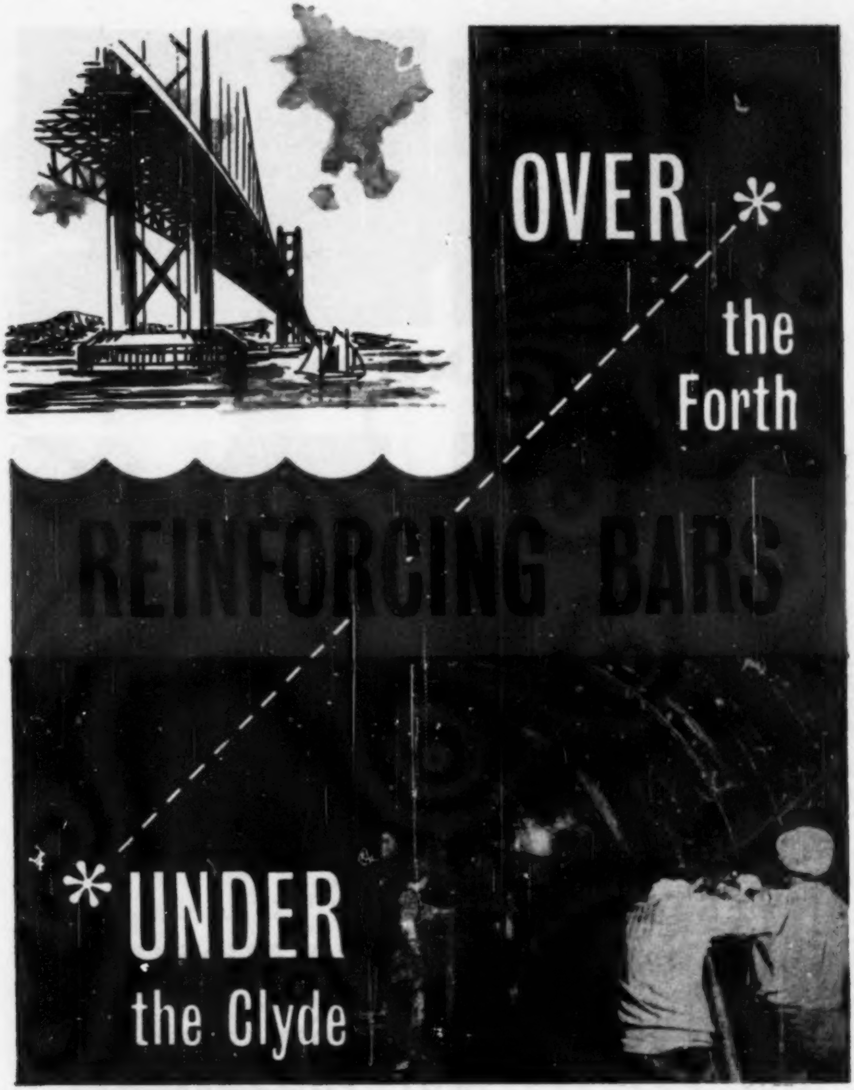
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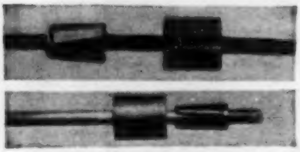

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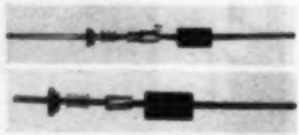

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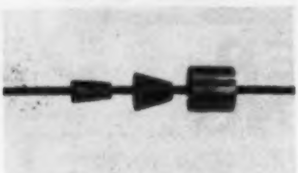

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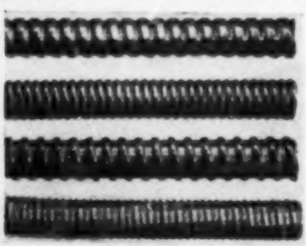

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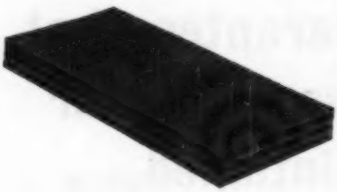

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42	16.5	168
50	19.7	245
60	23.6	357
87	34.2	772
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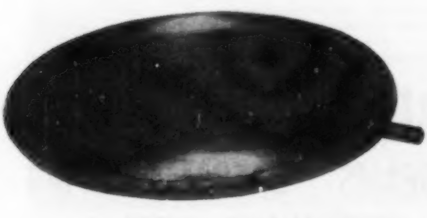

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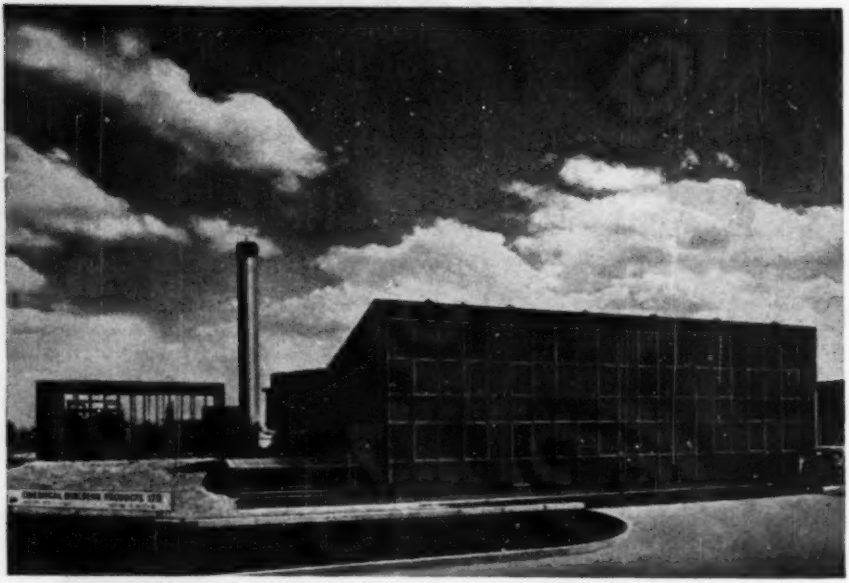

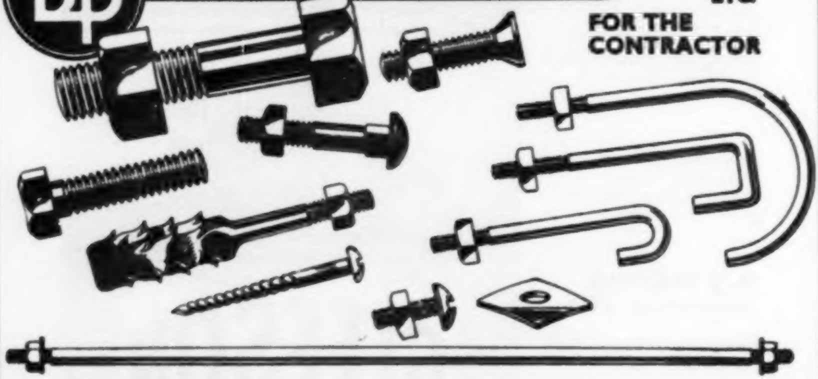

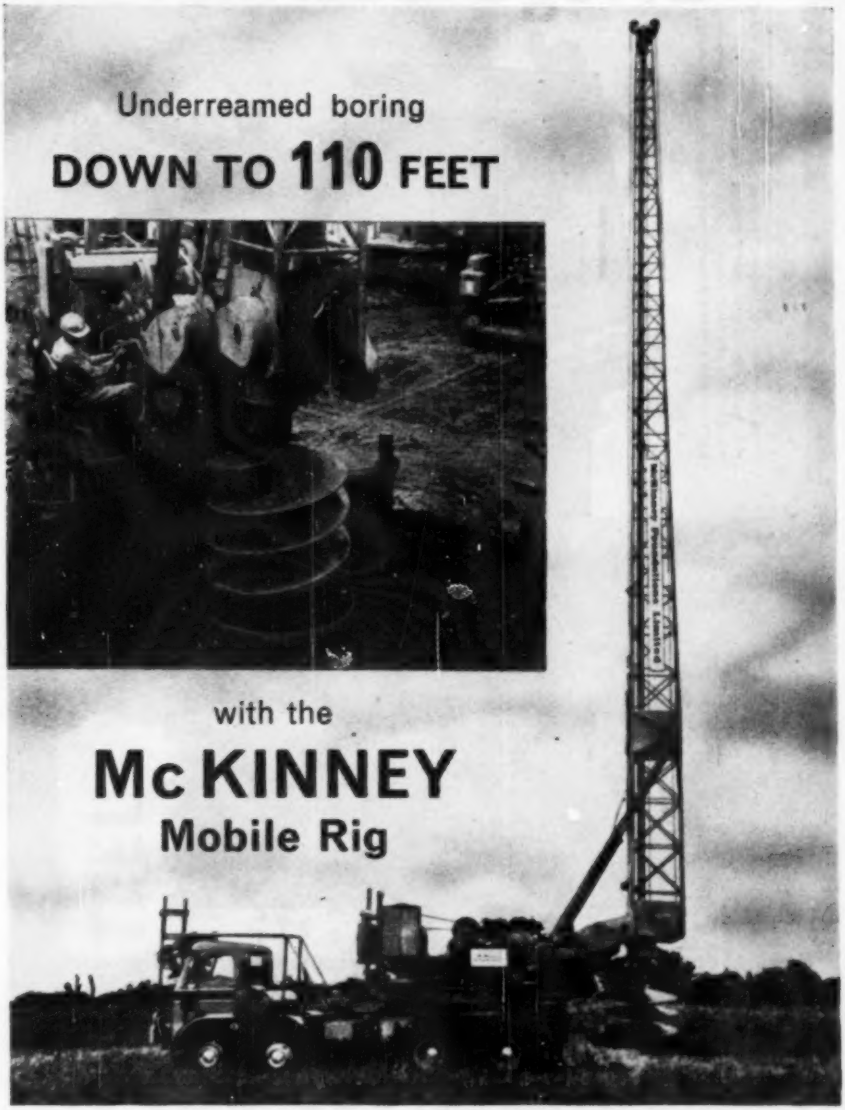
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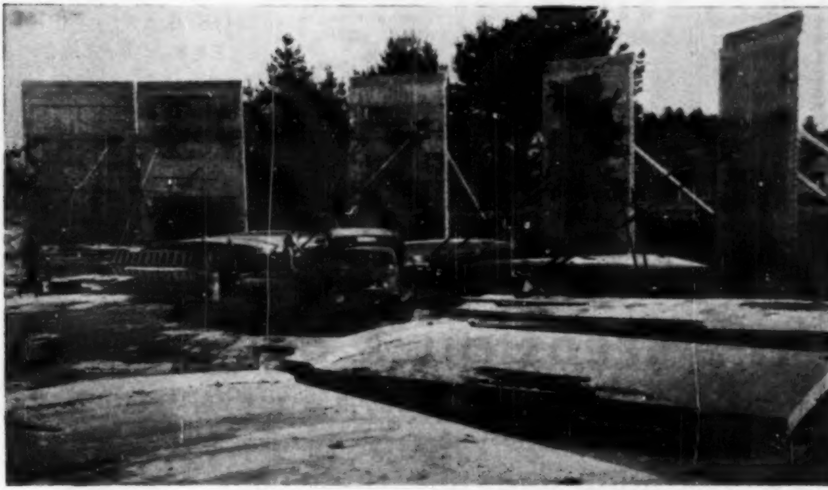

Auckland Star photograph of the 4-million gallon reservoir under construction.

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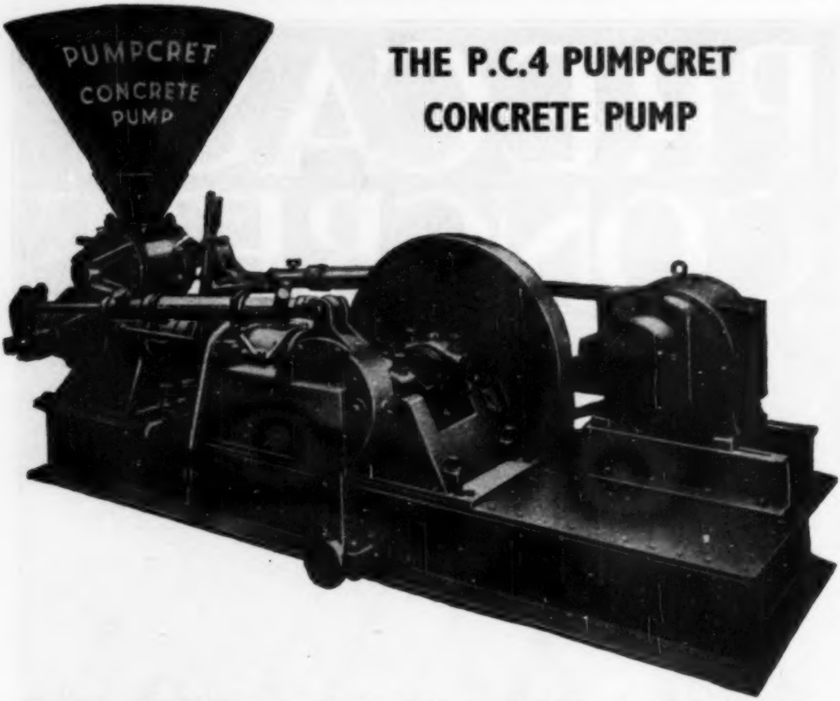

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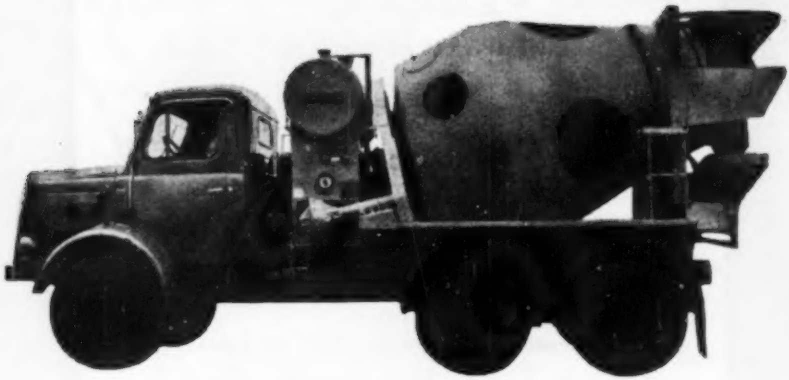

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Volume LV, No. 10. LONDON, OCTOBER, 1960.

EDITORIAL NOTES

A Code of Practice for Roads and Runways.

METHODS of designing concrete roads, airport runways, and similar pavings vary from those by which the thickness of the concrete slab and the amount of reinforcement are determined mainly from theoretical considerations to those based on precedent, that is, the adoption of designs which have proved successful in previous works. In Great Britain, design generally seems to be based on a combination of these two extreme methods, and the recommendations in a code* of practice published recently should do much to foster this sensible attitude. There is a complete absence of design formulæ, but references are given to sources of such data. A useful feature of the Code is the summary of the maximum loads which are permitted on the roads of Great Britain by the Road Acts and other legislation. Mention is also made of the load classification system (L.C.N.) of the Air Ministry in accordance with which the weights of aircraft and the strengths of paving are denoted; it would have been advantageous if this data had been collated and included in the Code. It is, however, made clear that the design of roads and runways is not solely a structural problem; the contour, surface, colour, and other characteristics are matters of importance from the point of view of safety or durability. The new test track constructed recently at Crowthorne by the Road Research Board has as its purpose the investigation of these and allied matters.

The Code, the scope of which is very comprehensive, deals not only with the design but also the construction of concrete pavings, with and without asphalt or other bituminous surfacings, in connection with roads, runways and other paved areas at airfields, and to a lesser degree with footpaths and cycle tracks. Grouted macadam and water-bound materials are also considered. It is acknowledged that constructional and other processes related to such pavings have changed considerably in recent years and continue to do so; therefore some of the recommendations may be applicable to practice only at the time the Code was prepared. Prestressed concrete pavings are dealt with superficially, but again a guide is given to other sources of information. Attention is drawn to the difficulty of cutting through a prestressed concrete slab for the purpose of

* British Standard Code of Practice CP. 2006 (1960): "Traffic Bearing Structures: Pavings". (The British Standards Institution. Price 30s.)

making repairs to underlying services, and therefore it is thought that the use of this form of construction for roads is limited. This seems to be insufficient reason to condemn a design if it proves otherwise economical; the specific difficulty can be overcome by good planning whereby services are laid alongside the road and in transverse ducts at the divisions between the lengths of prestressed slabs. These lengths in the case of roads are not likely to exceed 400 ft. as recommended in the Code, but may be considerably longer in the case of runways. An example of lengths of approximately 1000 ft. is given in the article commencing on page 371 of this number wherein several pavings constructed recently at various airports are described.

Most engineers will no doubt look to the Code for guidance in dealing with the controversial and difficult subject of whether joints should be provided in concrete roads and, if provided, what the spacing of the joints should be. Much depends on the location of the road, the ambient temperature when constructed, the degree of exposure, the frictional restraint of the foundation, the thickness of the slab, the amount of reinforcement, and even the type of aggregate as affecting the thermal expansion of the concrete. There seems to be reasonable consensus of opinion that a longitudinal joint should be provided in wide carriageways and the Code recommends such a joint in pavings more than 15 ft. wide if the slab is less than 12 in. thick. Does this mean that a joint is required in a 16-ft. road having an 11½-in. slab, but no joint in a road, say 30 ft. wide and 12 in. thick? The recommendations for the spacing of transverse joints are more precise and comprehensive since the factors taken into account are whether or not the slab is reinforced, the thickness of the slab and the amount of reinforcement, whether the joints are all of the expansion type or whether some are dummy construction joints, and whether the slab is to be laid in cold weather. Nevertheless, there are several factors which make it necessary to adopt spacings other than those given in the Code, for example, if more or less reinforcement than stated in the Code is provided, and if the foundation is not smooth; in the case of these and other variables the engineer must presumably use his discretion. Criticism might be made of the aggregate width of the joints in a specific length of slab, since the recommended width seems to be independent of the number of joints. It seems to be logical that there is less cumulative restraint if the joints are provided at smaller spacings and therefore the total width of the joints should be greater than if fewer joints were provided.

A problem which has arisen regarding the new motor-ways in Great Britain is whether the carriageways should be reinforced concrete slabs or whether they should be of "flexible" construction comprising a bituminous surfacing laid on a base of what is commonly called dry-lean concrete or more accurately a cement-bound granular base. The two methods of construction are seen on the London-Birmingham motorway, where there are seventeen miles of reinforced concrete road (the St. Albans by-pass road) and fifty-five miles of "flexible" construction. The latter type is undoubtedly cheaper to construct in the first instance than a reinforced concrete road, but reliable statements on the relative overall costs, that is taking into account the maintenance costs, do not seem to be available. Requests to the authorities for such data have been unrewarding. Some highway engineers contend that the choice is not between a reinforced concrete slab and a cement-bound granular base, but between the latter and bituminous macadam, asphalt

or similar construction. Cement-bound granular construction is therefore considered as a compromise between the more expensive reinforced concrete paving and the probably less durable bituminous-macadam, or similar, construction.

Prominence is properly given in the Code to the question of earthworks and the preparation of the ground forming the foundation under a paving. Roads on peaty soils are dealt with in detail. Emphasis is placed on the necessity to allow time to elapse after such operations as depositing filling, laying drains and the like before constructing the paving thereon, but this advice may not always accord with the requirement to get a road or runway in use as soon as possible after construction commences. Remarkable progress was made on the construction of the London–Birmingham motorway where fifty-five miles of dual carriageway and more than a hundred bridges were constructed in about a year and a half. Does such speedy construction permit enough time for the consolidation of earth embankments? A few decades ago the answer might well have been in the negative, but modern methods of compaction derived from recent advances in the study of soils have done much to reduce the risk of unforeseen settlement.

Comments on the terminology used in the Code are not uncalled for.

The ground forming the foundation of a road or runway is described by the term " sub-grade "; this is possibly an example of the use of a word which does not strictly describe the object to which it is applied, but the use of which is now so common among engineers that its distorted meaning is understood and accepted. Grading for a road (or railway) meant originally the earthworks necessary to prepare the ground to the required gradient (or grade) before constructing the road; later the road itself was called the grade (an Americanism) and the ground below this became known as the sub-grade. " Paving " seems an acceptable general term to describe a surfacing of any material laid on the ground, but " pavement " should not be used for carriageway. In this respect the Code is not consistent; for example, on one page where the acceptable word " paving " occurs three times and the unacceptable " pavement " seven times, there occur also such phrases as " road and airfield pavings ", " thickness of pavement ", and " road and airfield pavements ". A code of British origin should adopt the terms proper to this country; otherwise in the course of time our technical as well as our general language will become entirely foreign.

Some Early Sculpture in Concrete.

THE illustrations (page 364) show two of several gargoyles, finials, and other sculpture in concrete which were cast and placed in position on the cathedral of Uppsala, Sweden, in 1885. They were removed about sixty years later at the time of the restoration of the cathedral, but were on display for the first time at the exhibition held in Stockholm on the occasion of the Third International Congress of the Precast Concrete Industry.

The figures are in an excellent state of preservation, the features being very clearly cut and exhibiting no surface defects.

making repairs to underlying services, and therefore it is thought that the use of this form of construction for roads is limited. This seems to be insufficient reason to condemn a design if it proves otherwise economical; the specific difficulty can be overcome by good planning whereby services are laid alongside the road and in transverse ducts at the divisions between the lengths of prestressed slabs. These lengths in the case of roads are not likely to exceed 400 ft. as recommended in the Code, but may be considerably longer in the case of runways. An example of lengths of approximately 1000 ft. is given in the article commencing on page 371 of this number wherein several pavings constructed recently at various airports are described.

Most engineers will no doubt look to the Code for guidance in dealing with the controversial and difficult subject of whether joints should be provided in concrete roads and, if provided, what the spacing of the joints should be. Much depends on the location of the road, the ambient temperature when constructed, the degree of exposure, the frictional restraint of the foundation, the thickness of the slab, the amount of reinforcement, and even the type of aggregate as affecting the thermal expansion of the concrete. There seems to be reasonable consensus of opinion that a longitudinal joint should be provided in wide carriageways and the Code recommends such a joint in pavings more than 15 ft. wide if the slab is less than 12 in. thick. Does this mean that a joint is required in a 16-ft. road having an 11½-in. slab, but no joint in a road, say 30 ft. wide and 12 in. thick? The recommendations for the spacing of transverse joints are more precise and comprehensive since the factors taken into account are whether or not the slab is reinforced, the thickness of the slab and the amount of reinforcement, whether the joints are all of the expansion type or whether some are dummy construction joints, and whether the slab is to be laid in cold weather. Nevertheless, there are several factors which make it necessary to adopt spacings other than those given in the Code, for example, if more or less reinforcement than stated in the Code is provided, and if the foundation is not smooth; in the case of these and other variables the engineer must presumably use his discretion. Criticism might be made of the aggregate width of the joints in a specific length of slab, since the recommended width seems to be independent of the number of joints. It seems to be logical that there is less cumulative restraint if the joints are provided at smaller spacings and therefore the total width of the joints should be greater than if fewer joints were provided.

A problem which has arisen regarding the new motor-ways in Great Britain is whether the carriageways should be reinforced concrete slabs or whether they should be of " flexible " construction comprising a bituminous surfacing laid on a base of what is commonly called dry-lean concrete or more accurately a cement-bound granular base. The two methods of construction are seen on the London-Birmingham motorway, where there are seventeen miles of reinforced concrete road (the St. Albans by-pass road) and fifty-five miles of " flexible " construction. The latter type is undoubtedly cheaper to construct in the first instance than a reinforced concrete road, but reliable statements on the relative overall costs, that is taking into account the maintenance costs, do not seem to be available. Requests to the authorities for such data have been unrewarding. Some highway engineers contend that the choice is not between a reinforced concrete slab and a cement-bound granular base, but between the latter and bituminous macadam, asphalt

or similar construction. Cement-bound granular construction is therefore considered as a compromise between the more expensive reinforced concrete paving and the probably less durable bituminous-macadam, or similar, construction.

Prominence is properly given in the Code to the question of earthworks and the preparation of the ground forming the foundation under a paving. Roads on peaty soils are dealt with in detail. Emphasis is placed on the necessity to allow time to elapse after such operations as depositing filling, laying drains and the like before constructing the paving thereon, but this advice may not always accord with the requirement to get a road or runway in use as soon as possible after construction commences. Remarkable progress was made on the construction of the London–Birmingham motorway where fifty-five miles of dual carriageway and more than a hundred bridges were constructed in about a year and a half. Does such speedy construction permit enough time for the consolidation of earth embankments? A few decades ago the answer might well have been in the negative, but modern methods of compaction derived from recent advances in the study of soils have done much to reduce the risk of unforeseen settlement.

Comments on the terminology used in the Code are not uncalled for.

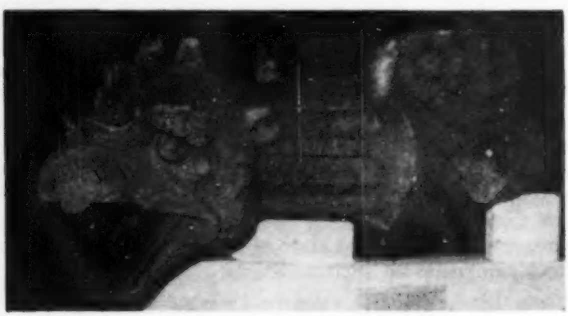
The ground forming the foundation of a road or runway is described by the term "sub-grade"; this is possibly an example of the use of a word which does not strictly describe the object to which it is applied, but the use of which is now so common among engineers that its distorted meaning is understood and accepted. Grading for a road (or railway) meant originally the earthworks necessary to prepare the ground to the required gradient (or grade) before constructing the road; later the road itself was called the grade (an Americanism) and the ground below this became known as the sub-grade. "Paving" seems an acceptable general term to describe a surfacing of any material laid on the ground, but "pavement" should not be used for carriageway. In this respect the Code is not consistent; for example, on one page where the acceptable word "paving" occurs three times and the unacceptable "pavement" seven times, there occur also such phrases as "road and airfield pavings", "thickness of pavement", and "road and airfield pavements". A code of British origin should adopt the terms proper to this country; otherwise in the course of time our technical as well as our general language will become entirely foreign.

Some Early Sculpture in Concrete.

THE illustrations (page 364) show two of several gargoyles, finials, and other sculpture in concrete which were cast and placed in position on the cathedral of Uppsala, Sweden, in 1885. They were removed about sixty years later at the time of the restoration of the cathedral, but were on display for the first time at the exhibition held in Stockholm on the occasion of the Third International Congress of the Precast Concrete Industry.

The figures are in an excellent state of preservation, the features being very clearly cut and exhibiting no surface defects.

Some Early Sculpture in Concrete (*see page* 363)



Design of Biaxially-loaded Columns by the Ultimate-load Method.—I.

By F. N. PANNELL, M.Sc.Tech., B.Sc.(Eng.), A.M.I.C.E., A.M.I.Struct.E.

It is not practicable to portray the basic equation relating the load causing failure to the bending moment causing failure as a set of graphs applying to all biaxially-loaded columns. If, however, the arrangements of reinforcement considered are restricted to those in which there are nearly equal amounts of reinforcement near each side, the charts given in this article can be derived and provide a simply applied aid to design.

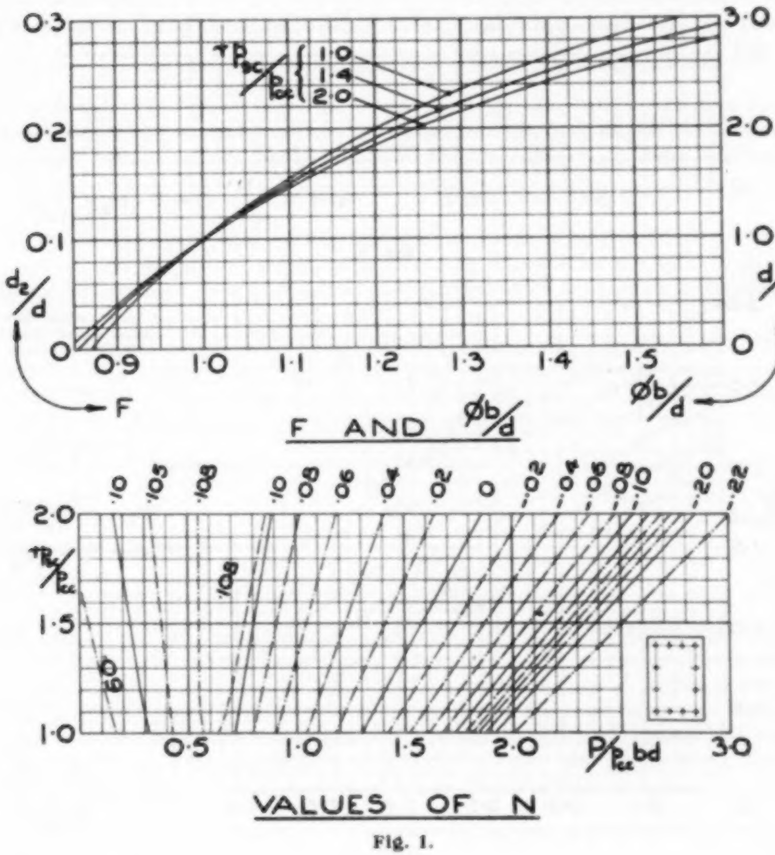


Fig. 1.

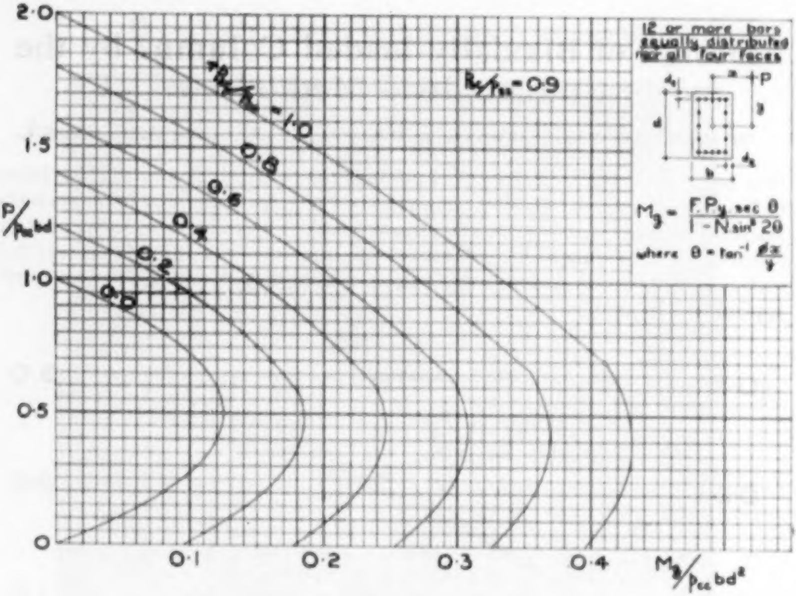

12 or more bars equally distributed near all four faces
P
d
b
$M_y = \frac{F.P_y \sec\theta}{1 - N\sin^2 2\theta}$
where $\theta = \tan^{-1}\frac{\phi x}{y}$
P/p_cc bd
M_y/p_cc bd²
2·0
1·5
1·0
0·5
0
0·1
0·2
0·3
0·4
1·0
0·8
0·6
0·4
0·2
0·0

Fig. 2.

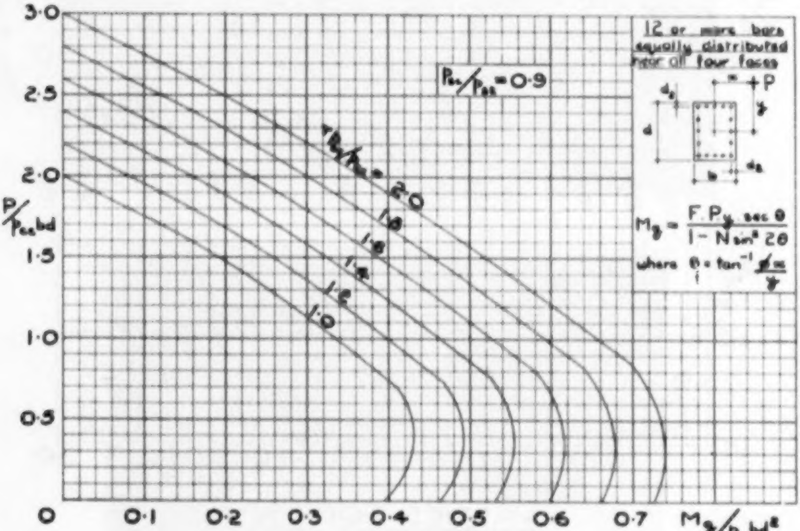

12 or more bars equally distributed near all four faces
P
d
b
$M_y = \frac{F.P_y \sec\theta}{1 - N\sin^2 2\theta}$
where $\theta = \tan^{-1}\frac{\phi x}{y}$
P/p_cc bd
M_y/p_cc bd²
3·0
2·5
2·0
1·5
1·0
0·5
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
2·0
1·8
1·6
1·4
1·2
1·0

Fig. 3.

Columns with Twelve or More Bars.

Columns containing twelve or more bars equally distributed around the sides may be considered, without significant error, as though the reinforcement were distributed in the form of a cylinder. If the curves comparing the loads causing the failure of such a column to the corresponding bending moments in a vertical plane are plotted for all vertical planes passing through the longitudinal axis of the column, they could be said to enclose a volume. For a column of breadth b and depth d it can be shown[1] that by multiplying all the ordinates of a horizontal section through such a volume by the factor $\phi = \frac{M_{by}}{M_{bx}}$, the surface of such a section is transformed to coincide with that of an equivalent square column. M_{by} and M_{bx} are the moments causing failure of a column of "balanced" design when the load causing failure acts in the planes of the Y and X axes respectively. If this "failure load" P acts at eccentricities x and y, the actual radial moment M is $P\sqrt{x^2 + y^2}$ and would be $P\sqrt{(\phi x)^2 + y^2}$ for the transformed surface. This expression is more conveniently written $M = Py \sec \theta$ in which $\theta = \tan^{-1}\frac{\phi x}{y}$.

Different transformed surfaces are obtained for different depths d_2 of the concrete cover of the reinforcement. If the case in which $d_2 = 0{\cdot}1d$ is taken as a standard, other surfaces can be related to it by multiplying all radial bending moments by a factor $F = \frac{M_{bb}}{M_{ba}}$, in which M_{bb} is the bending moment in the direction of the major transverse axis causing failure of a column of balanced design when $d_2 = 0{\cdot}1d$, and M_{ba} is the corresponding bending moment for the ratio of d_2/d under consideration. The true radial bending moment for any section is therefore given by

$$M = FPy \sec \theta \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(a)}$$

If the moment causing failure due to a load P be M_g when P acts on the major axis and M_d when it acts on a diagonal, it can be shown that as θ increases from 0 deg. to 45 deg. the moment causing failure changes smoothly from M_g to M_d and that, for values of θ intermediate between these two cases, if $N = \frac{M_g - M_d}{M_g}$

$$M = M_g(1 - N \sin^2 2\theta) \quad . \quad . \quad . \quad . \quad . \quad \text{(b)}$$

From equations (a) and (b)

$$M_g = \frac{FPy \sec \theta}{1 - N \sin^2 2\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

This formula gives the actual bending moment in terms of M_g, the bending moment on the major axis, and the load causing failure of the column can be determined from the load-moment curve for M_g. As the formula contains an empirical term, tests have been made within the possible ranges of the position of the neutral plane, steel-ratios, and ratios of cover of concrete to depth of column. It was found that the load causing failure was predicted in every case within an accuracy of 1 per cent. of the theoretical value obtained from the basic equations.

(1).—F. N. Pannell. "The design of biaxially loaded columns by ultimate load methods." Magazine of Concrete Research, Vol. 12, No. 35. July 1960.

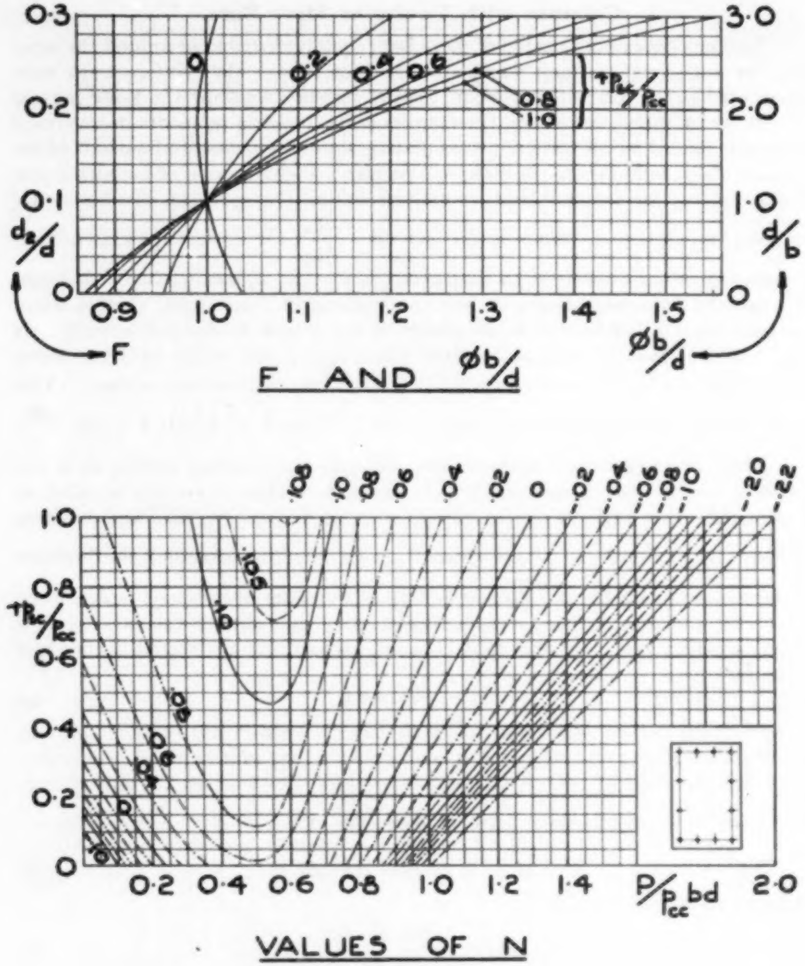


Fig. 4.

The charts for N, F, ϕ and M_g (*Figs.* 1 to 4) are based on the ultimate-load equation revised to conform to British Standard Code of Practice No. 114 as far as working loads and reduced stresses are concerned. The adjusted equations for these idealised columns are given in Appendix I.

Example 1.—A column of 1 : 2 : 4 concrete, 20 in. by 36 in. in cross-section, contains 16 1-in. diameter mild steel bars equally distributed near all four sides. The cover of concrete is 1½ in. Ascertain that the column is strong enough to

support a load of 250,000 lb. at eccentricities of 15 in. and 5 in. parallel to the long and short sides of the column respectively.

The ratio $d/b = \frac{36}{20} = 1{\cdot}8$, $\frac{d_2}{d} = \frac{2}{36} = 0{\cdot}056$,

$$\frac{r \cdot p_{se}}{p_{ce}} = \frac{16 \times 0{\cdot}785 \times 18{,}000}{720 \times 760} = 0{\cdot}413,\ p_{ce}bd = 546{,}000 \text{ lb.},\ \frac{P}{p_{ce}bd} = 0{\cdot}457.$$

From *Fig.* 4, $F = 0{\cdot}955$, $\phi = 1{\cdot}8 \times 1{\cdot}1 = 1{\cdot}98$, $N = 0{\cdot}095$.

$$\text{Tan } \theta = \frac{1{\cdot}98 \times 5}{15} = 0{\cdot}66, \text{ therefore } \theta = 33^\circ\ 30' \text{ and } \sec\theta = 1{\cdot}199,\ \sin^2 2\theta = 0{\cdot}847.$$

$$\text{From formula (1), } M_\theta = \frac{0{\cdot}955 \times 250{,}000 \times 15 \times 1{\cdot}199}{1 - (0{\cdot}095 \times 0{\cdot}847)} = 4{,}650{,}000 \text{ in.-lb.}$$

$$\text{therefore } \frac{M_\theta}{p_{ce}bd^2} = \frac{4{,}650{,}000}{546{,}000 \times 36} = 0{\cdot}236.$$

From *Fig.* 2, $\frac{r \cdot p_{se}}{p_{ce}} = 0{\cdot}39$ (by interpolation). The column is therefore adequate with an area of reinforcement about 5 per cent. in excess of the requirements.

The planes X and Y could have been interchanged but it is best to select these planes such that θ is less than 45 deg. and in any case θ should not exceed, say, 65 deg.

Example 2.—Design a column of 1 : 2 : 4 concrete to withstand an axial load of 200,000 lb. together with moments of 1,000,000 in.-lb. and 2,000,000 in.-lb. about the minor and major axes respectively. A suitable size of column can be chosen by means of *Table* I. The table is for 1 : 2 : 4 concrete only but may be used for other concretes by multiplying the values of $\frac{\sqrt{P}}{e}$ by $\sqrt{\frac{p_{ce}}{760}}$. Two values of b/d are given, intermediate values can be interpolated.

Assume that d is approximately equal to $2b$. Since $x = 5$ in. and $y = 10$ in. e is approximately $\sqrt{10^2 + (5 \times 2)^2} = 14{\cdot}1$ in., therefore $\frac{\sqrt{P}}{e} = \frac{\sqrt{200{,}000}}{14{\cdot}1} = 31{\cdot}7$.

From *Table* I $\frac{P}{p_{ce}bd} = 0{\cdot}60$, $\frac{r \cdot p_{se}}{p_{ce}} = 0{\cdot}55$. Hence $bd = \frac{P}{0{\cdot}60 p_{ce}} = 440$ sq. in., say, 15 in. by 30 in. (Any method of estimating the size of the column may be used.)

Let $d_2 = 2$ in., then $\frac{d_2}{d} = 0{\cdot}067$, $\frac{d}{b} = 2$, $p_{ce}bd = 342{,}000$ lb., $\frac{P}{p_{ce}bd} = 0{\cdot}585$ and $\frac{r \cdot p_{se}}{p_{ce}} = 0{\cdot}55$.

From *Fig.* 4, $F = 0{\cdot}962$, $\phi = 2 \times 1{\cdot}15 = 2{\cdot}3$, and $N = 0{\cdot}101$.

Substituting in equation (1) $\frac{M_\theta}{p_{ce}bd^2} = 0{\cdot}315$ and, from *Fig.* 2, $\frac{rp_{se}}{p_{ce}} = 0{\cdot}65$.

This is sufficiently close to the assumed value of 0·55. The required area of reinforcement is therefore $\frac{0{\cdot}65 \times 760 \times 450}{18{,}000} = 12{\cdot}35$ sq. in., say sixteen 1-in. bars.

TABLE I.—APPROXIMATE SIZES FOR MULTIPLE-BAR COLUMNS (1 : 2 : 4 CONCRETE)

$\frac{\sqrt{P}}{e}$ $(d = b)$	$\frac{\sqrt{P}}{e}$ $(d = 2b)$	$\frac{P}{p_{cc}bd}$	$\frac{r \cdot p_{sc}}{p_{cc}}$
3	2	0·1	0·75
8	5	0·2	0·70
14	10	0·3	0·65
21	15	0·4	0·65
30	20	0·5	0·65
45	30	0·6	0·55
65	50	0·7	0·48
100	70	0·8	0·41
140	100	0·9	0·36
230	160	1·0	0·32
390	280	1·1	0·30
890	620	1·2	0·30

P is in pounds (lb.).

e is approximately $\sqrt{y^2 + \left(\frac{d}{b}.x\right)^2}$.

For values of $\frac{P}{p_{cc}bd}$ less than 0·5, obtain the size from $\frac{Pe}{p_{cc}bd^2} = 0{\cdot}325$.

The calculations for the design charts were carried out on the electronic computor at Manchester University.

(*To be continued.*)

The Tallest Reinforced Concrete Building in U.S.A.

THE Americana Hotel, which is to be built in New York, it is reported in Engineering News-Record, will be the tallest reinforced concrete structure in the U.S.A. It will be 420 ft. high and comprise forty-six stories in one part and twenty-four elsewhere. The taller structure will have walls 8 in. or 12 in. thick for the bottom thirty stories to resist horizontal forces. Above the fourth floor the columns will be 18 in. wide and up to 48 in. broad. Below the fourth floor there will be composite columns of concrete and structural steel at intervals of about 24 ft. in one direction and 14 ft. in the other. The floors will be of flat-slab construction about 7½ in. thick. The columns will be of lightweight concrete having a crushing strength at twenty-eight days of at least 4000 lb. per square inch. Reinforced concrete has been adopted because of its cheapness and because it provides greater rigidity than a steel frame.

Concrete Pavings at Airports.

THE design and construction of pavings of various types which have been laid recently at airports in this country and abroad are described in the following.

Prestressed Concrete Pavings at Gatwick.

During the past two years, two areas of prestressed concrete paving have been constructed at Gatwick Airport, Surrey, and the construction of a third area is nearing completion.

The first of these pavings is the apron completed in 1958 in front of the hangar for Transair, Ltd. (now British United Air Services, Ltd.). The apron is 290 ft. by 230 ft. and is a 5-in. slab prestressed by cables at 3-ft. centres longitudinally and at 5-ft. centres transversely. Each cable comprises twelve 0·2-in. wires. The slab, which is laid on two layers of waxed paper overlying a 3-in. sub-base of 10 : 1 concrete (*Fig.* 2), was constructed in strips each 15 ft. wide and extending the entire length of the apron. Each strip was concreted completely in one day. On the following day three of the five longitudinal cables were tensioned to prevent shrinkage cracks. Alternate strips were laid first and the transverse cables were threaded through ducts in these strips of slab and continued in sheaths across the formation for the intermediate strips. Three days after the strips had been laid, the remainder of the longitudinal cables were tensioned and the transverse cables were then tensioned. Later the apron was extended at one corner, and the cables were therefore lengthened using double-ended anchorages. Some months after completion, loading tests were carried out by the Road Research Laboratory. Most of the tests were made adjacent to the longitudinal joints. A thousand applications of a load of 19 tons on an 18-in. diameter plate, which is equivalent to L.C.N. 60, produced only slight spalling at the joints. Repeated loading of 27·5 tons (L.C.N. 100) produced cracks which closed after removal of the load. A single load of 69 tons followed by twenty-five applications of 51·7 tons produced no cracks.

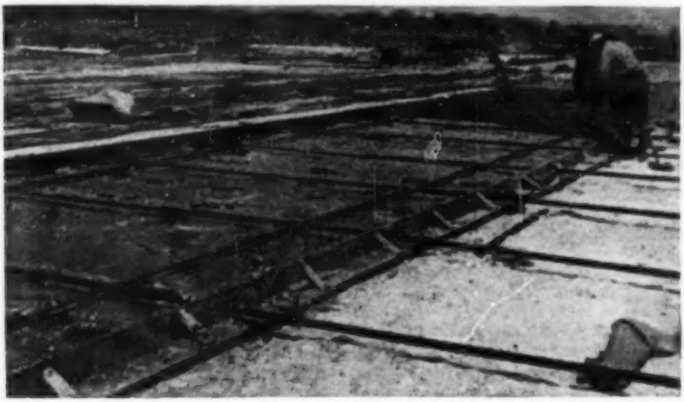


Fig. 1.

The consulting engineers for this apron were Messrs. A. J. and J. D. Harris, and the contractors were Sir Alfred McAlpine & Sons, Ltd. The prestressing cables are the Freyssinet type. Gifford-Udall double-anchorages were used where the cables were extended.

An apron (*Fig.* 1) in front of a new hangar for Overseas Aviation, Ltd., was completed recently and is 132 ft. by 150 ft.;

it will be extended to 240 ft. by 500 ft. in the future. There is an approach strip 60 ft. wide. The concrete slab is 6¼ in. thick and is prestressed in two directions by 1⅛-in. steel-alloy bars at 7-ft. 6-in. centres longitudinally and 6-ft. 9-in. centres transversely. The bars are wrapped in tape and therefore are not bonded to the concrete. Sleeve anchors are used extensively. The apron is designed for L.C.N. 50. The subsoil is clay, and hoggin was used where filling was required. The construction comprises a 4-in. sub-base of rolled lean concrete on which there is a 1-in. layer of sand, covered with building paper, on which the 6¼-in. concrete slab is laid. The concrete slab was placed in strips 15 ft. wide between edge strips 7 ft. 6 in.

tudinally from both ends, with no intermediate jacking, by ⅞-in. strands at 3-ft. centres. The transverse prestressing is by $\frac{7}{16}$-in. strands at 5-ft. centres. The foundation of the prestressed slabs is partly of clay and partly of hardcore, on which is placed a 6-in. layer of hoggin. The sub-base is lean concrete 4 in. thick, on which is a 1-in. layer of sand. The 6-in. prestressed concrete slab, which is constructed in strips 15 ft. wide, is laid on building paper faced with polythene overlying the sand. The net tensile force in each longitudinal strand is 74,500 lb. in the 970-ft. strips, and 20,000 lb. in the 250-ft. strip. There is a force of 17,500 lb. in each transverse strand. At one end of the taxiway there is a curved section (*Fig.* 3), the construction of which is 12 in.

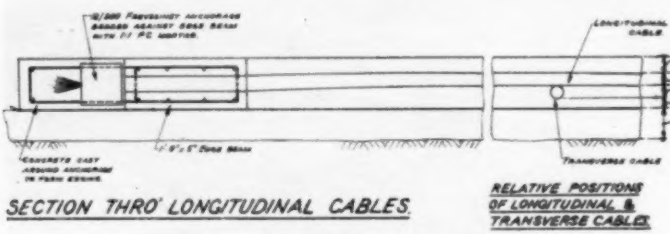


Fig. 2.

wide which had been cast about a week earlier. One day after casting each strip, a partial prestress was applied to the 150-ft. length of apron to neutralise shrinking and prevent cracking. The slab is designed to have a residual prestress of about 100 lb. per square inch in both directions at the centre of the apron. The purpose of the layer of sand is to reduce the frictional restraint.

The consulting engineers for this apron were Messrs. Donovan Lee & Partners, and the contractors were Messrs. J. Jarvis & Sons, Ltd. The prestressing bars are Macalloy bars; this is the first instance of their use in a concrete apron in Great Britain.

The third paving, which is at present under construction, is a taxiway in a maintenance area. The taxiway is 60 ft. wide and the prestressed concrete pavings comprise three straight sections, two of which are each 970 ft. long, and one 250 ft. long. Each section is prestressed longi-

of plain non-prestressed concrete with dowelled joints.

The consulting engineers to the Ministry of Aviation for the taxiway are Messrs. Frederick S. Snow & Partners, and the contractors are The Turriff Construction Corporation, Ltd.; P.S.C. equipment is being used for the prestressing.

With reference to the costs of these pavings, it has been stated that in the case of the apron at the Transair hangar, a 5-in. prestressed concrete slab may be thicker than is required for a lightly-loaded apron; the cost was about 48*s.* 6*d.* per square yard which is no dearer than an ordinary reinforced concrete slab, and a better paving results. The low cost in this case is attributed to the inexpensive excavation required. A similar prestressed apron proposed to be constructed near the Transair hangar will have a 4½-in. slab and the transverse cables will be in the concrete sub-base. The alternative to the 6¼-in. prestressed concrete

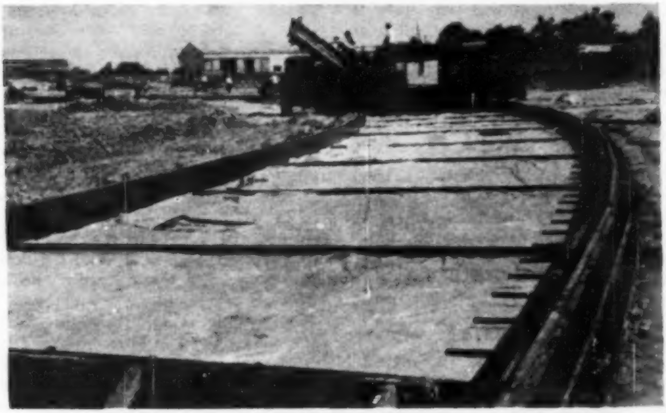


Fig. 3.

slab at the Overseas Aviation hangar would have been a 9-in. plain concrete slab with dowelled joints. The 6½-in. slab, if suitably prestressed, could support a greater load than that for which it has been designed and would then be competitive in cost with the thicker plain concrete jointed slab required. On a clay soil, however, it is essential for the joints to be watertight; in prestressed construction there are no joints. Even for the moderate design load the initial cost of the prestressed concrete paving was only slightly greater than a plain concrete slab with joints, but the elimination of the maintenance of the joints and the greater durability of prestressed concrete favour the latter type of construction.

Reinforced Concrete Runway at Nandi Airport, Fiji.

A new runway two miles long at Nandi, Fiji, was put into use last year. The original north-south runway, which was 6700 ft. long and 150 ft. wide, was covered by an 8-in. slab of reinforced concrete and has been extended by 3700 ft., the extension comprising a 14-in. reinforced concrete slab (*Fig.* 4) laid on compacted filling 4 ft. to 10 ft. deep. This work is the first of several operations by means of which the airport will be enlarged. The entire works, which commenced in August 1958 and are expected to be completed this year, involve 750,000 cu. yd. of earth-works, 100,000 cu. yd. of concrete, and 10,000 cu. yd. of hot-laid bituminous paving. More than 500,000 cu. yd. of earth was removed from the site of the extension of the main runway. The material available for the filling was a clay the characteristics of which are very poor from the point of view of compaction; the upper 15 in. of filling therefore consists of river gravel. The concrete pavings were laid in a continuous operation by a train of machines. The concrete was transported to the site in side-tipping wagons and a layer was deposited on building paper by the first spreader machine. Sheets of steel fabric were then laid and fixed by hand. Another layer of concrete was deposited by a second spreader machine which left the surface of the non-compacted concrete 1 in. above the tops of the side forms. A single pass by each of two finishing machines compacted the concrete, the surface of which was finally finished with a stiff brush. Joints were cut at 50-ft. intervals. The concrete was sprayed with a curing liquid and then protected by aluminium awnings. An average of 1000 lin. ft. of paving 20 ft. wide was laid per day for five months, the greatest production being 2600 ft. in one working day of almost twenty-four hours.

CONCRETE.—The aggregates are basalt and andesite river gravel, in three gradings, namely 1½ in. to ¾ in.; ¾ in. to ¼ in., and ¼ in. down; the latter material was

rather coarse, so that it was necessary to import a wind-blown sand graded from sieves No. 8 to No. 100. Most of the materials are rounded and only about 5 per cent. required to be crushed. The cement, which was a rapid-hardening type, was imported from Japan in paper bags.

Two grades of concrete were used for the paving. Grade No. 1 is a dry-lean concrete for the 4-in. sub-base and contains 300 lb. of cement per cubic yard, and had a water-cement ratio of 0·6. Eight-thousand cubic yards of this concrete was laid for the 3700-ft. extension. It is reported that the surface was so uneven that a concrete with a higher water-cement ratio and of less strength was used

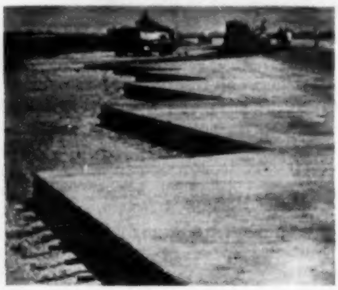


Fig. 4.

for the remaining area involving 22,000 cu. yd. which was placed between forms. The proportions of the aggregates are 36 per cent. of 1½ in. down, 24 per cent. of ¾ in. down, 30 per cent. of ¼ in. down, and 10 per cent. of wind-blown sand. The cement content is 300 lb. per cubic yard. The water-cement ratio varied considerably with no apparent effect on the strength; on a cool cloudy morning the ratio was about 0·75, but by afternoon with a sea breeze and an air temperature up to 100 deg. F. it was increased to 0·9 in order to off-set the evaporation during transport. The average compressive strength of 12-in. cylinders at twenty-eight days was 1800 lb. per square inch.

Concrete of Grade No. 2 was used for the paving laid on the sub-base and is the highest quality required on the contract. The slabs are reinforced with mesh placed 1½ in. from the top. For the first 42,000 cu. yd. of this concrete no admixtures were used. The cement content was 550 lb. per cubic yard, and the water-cement ratio was between 0·56 and 0·60. These values are higher than those specified; therefore tests were made with various admixtures in order to reduce them. The final 22,000 cu. yd. of concrete therefore incorporated a Swedish product called "Discon" in the proportion of ¼ lb. per 112 lb. of cement. It is a retarder and its use also enabled the cement to be reduced to 520 lb. per cubic yard and the water-cement ratio to between 0·46 and 0·50. Good workability was achieved and the average strengths of cylinders was 4750 lb. per square inch at twenty-eight days. The proportions of aggregate, in the order given previously, are 30, 35, 24 and 11 per cent.

The contractors, who carried out the work for the New Zealand Ministry of Works in association with the Australian Department of Civil Aviation, were Messrs. Taylor Woodrow (Overseas) Ltd., and Messrs. D. B. Waite of New Zealand.

A Long Runway at Stockholm.

The runway at the new airport at Arlanda, Stockholm, is about two miles in length and has been constructed to accommodate civil jet-aircraft. The runway is 230 ft. wide and comprises a central concrete strip 148 ft. wide and two asphalt edge strips each 41 ft. wide. The reinforced concrete slab is about 9 in. thick. The area of slab including the taxiways is 536,000 sq. yd., which required 30,000 tons of cement and 4500 tons of reinforcement. The average area of slab laid in each working shift was about 4600 sq. yd. The slab is designed to support aircraft up to 220 tons in weight on four wheels, or 400 tons if future aircraft should be equipped with eight wheels. (For comparison, the weight of a DC-8 aircraft is about 150 tons.)

The site is in part on rock and elsewhere on clay, which is drained and stabilised by means of sand pillars. Steel pipes were forced down to an average depth of 32 ft., filled with wet sand, and then withdrawn, leaving the sand insitu. In the areas which are entirely clay there are about 50,000 pillars.

The contractors for the construction of the runway were Skånska Cementjuteriet. Work commenced in May 1958 and was completed in eighteen months.

Fig. 5.

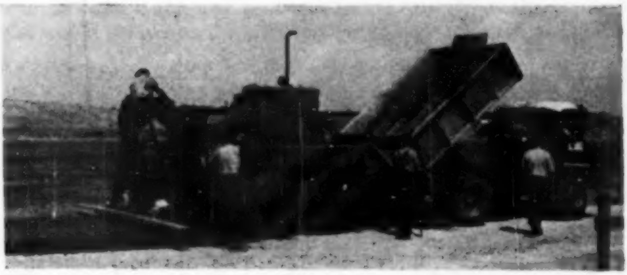


Fig. 6.

Soil-cement Runways at Coventry.

Construction commenced in March last on the civic aerodrome at Baginton, near Coventry. · In the first of the four phases of this work there is a main runway 5300 ft. long and 150 ft. wide which will be linked to the existing terminal area by a taxiway 400 ft. long and 60 ft. wide. Subsequently another runway 4300 ft. long and 150 ft. wide and a perimeter track are to be constructed and the main runway is to be extended to 9000 ft. in length.

The main runway has a "flexible" paving comprising two 6-in. layers of soil-cement and a surfacing of 2 in. of hot-rolled asphalt. Where an unstable foundation was exposed upon excavation, a third 6-in. layer of soil-cement is provided. For the bottom layer, or for the two lower layers in the case of a three-layer construction, the materials were processed insitu and compacted by a train of machines (*Fig.* 5) which carried out the operations in a single pass. For the upper layer, the cement and soil were mixed in a mixing plant and spread and compacted by the equipment shown in *Fig.* 6. A soil-cement runway was adopted because of the stable and easily drained sandy gravel subsoil. Cylinders, 4 in. long and 2 in. in diameter, of the compacted soil-cement mixtures had crushing strengths up to 600 lb. per square inch at seven days when the cement content was 8 per cent. The compressive strengths acceptable are 150 lb. to 500 lb. per square inch for the lower layer, and 350 lb. to 600 lb. per square inch for the upper layers; a limiting coefficient of variation of 30 per cent. is specified. The cement is an extra-rapid-hardening type and is ordinary Portland cement with 2 per cent. of calcium chloride. The soil is contaminated with organic matter as the site has been irrigated for a long period by sewage.

The design of the works was carried out by Mr. Granville Berry, M.I.C.E., the City Engineer and Surveyor of Coventry. The civil engineering contractors are Messrs. G. Percy Trentham, Ltd.

New Works at London Airport.

New works proposed for London Airport include taxiways and hard-standings at the northern apex. The contractors are Sir Lindsey Parkinson & Co., Ltd.

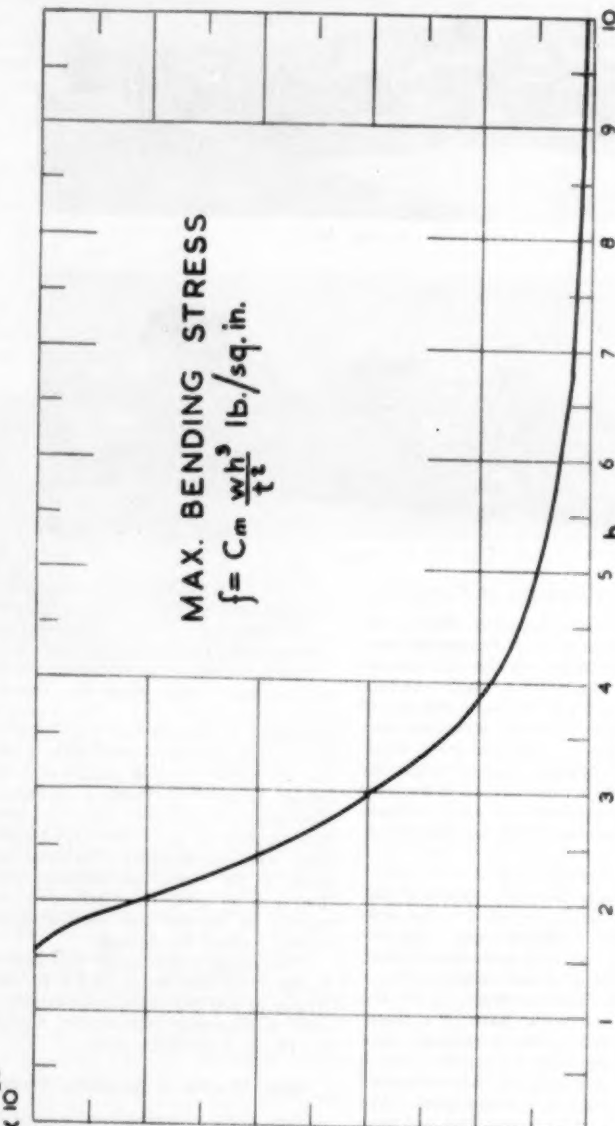


Fig. 1.

(See facing page.)

Bending of the Walls of Partly-full Cylindrical Tanks.

By J. D. DAVIES, M.Sc., A.M.I.C.E., A.M.I.Struct.E.

THE analysis of the stresses in the wall of a partly-full cylindrical reinforced concrete tank is more complex than in the case of a tank which is completely full. The following method provides a simple means of calculating these stresses in the most adverse case of a partly-full tank, which is a condition not uncommon in some industrial plants.

If a horizontal cut be made through the wall at the level C of the water surface (*Fig.* 2a) and if the wall be unrestrained at the bottom, the lower part of the wall CA would behave as the wall of a completely full tank and rotate through an angle θ (*Fig.* 2b) equal to $\frac{R^2 w}{Et}$. The upper part CB would not deform.

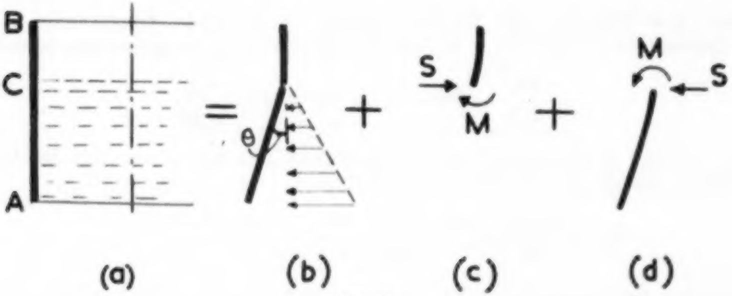


Fig. 2.

For the wall to be continuous at the horizontal plane at C there must be equal and opposite shearing forces and moments on either side of the plane and corresponding shearing and bending stresses in the wall. Assuming the directions of these forces and moments to be as shown at (c) and (d) in *Fig.* 2, their magnitudes may be evaluated from the two conditions of compatibility that the two parts of the wall must have the same slope and deflection at the plane C. If θ is the slope in radians of the wall at plane C and Y is the radial deflection, then $\theta_{CA} + \theta_{CB} = \theta$ and $Y_{CA} = Y_{CB}$.

An analysis of these conditions shows that the bending moment M on the wall is greatest when the tank is half-full, and in this case S, the shearing force at the plane C, is equal to zero. Therefore, if the effect of a radially-applied bending moment around the edge of the wall of depth equal to half the depth of the tank is known, the maximum bending stresses set up in the wall of a partly-full tank can be calculated as follows.

The elastic behaviour of the cylinder (*Fig.* 3) of height d subjected to a uniform bending moment (at the edge) of magnitude M per unit of arc may be determined from the well-known equation

$$\frac{d^4 y}{dx^4} + \frac{12(1-\mu^2)}{R^2 t^2} y = 0$$

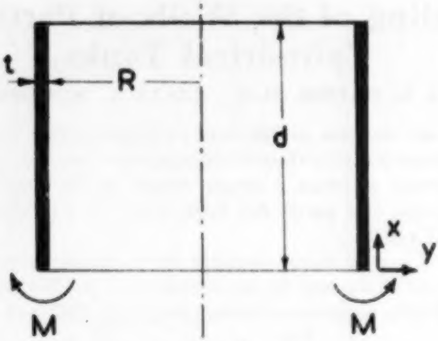


Fig. 3.

where μ is Poisson's ratio for the material of the wall. For concrete $(1-\mu^2)$ is approximately equal to unity, and the equation in the foregoing may be written

$$\frac{d^4y}{dx^4} + 4\beta^4 y = 0, \text{ in which } \beta = \frac{\sqrt[4]{3}}{\sqrt{Rt}}.$$

The solution of this equation gives the angular rotation of the edge due to the bending moment M per foot of the wall as

$$\theta_m = \frac{4MR^2}{Etd^3}\left[\frac{\text{Sinh } \beta d.\text{Cosh } \beta d + \sin \beta d.\cos \beta d}{\text{Sinh}^2 \beta d - \sin^2 \beta d}\right](\beta d)^3$$

Therefore, the rotation is a function of βd and the effect of a bending moment at the edge depends on the dimensionless quantity $\frac{h}{\sqrt{Rt}}$ which may be called the "shape-factor" of the tank.

For a half-full tank, $2\theta_m = \theta = \frac{R^2 w}{Et}$; therefore

$$M = \frac{wh^3}{64}\left[\frac{\text{Sinh}^2 \frac{\beta h}{2} - \sin^2 \frac{\beta h}{2}}{\text{Sinh } \frac{\beta h}{2}.\text{Cosh } \frac{\beta h}{2} + \sin \frac{\beta h}{2}.\cos \frac{\beta h}{2}}\right]\frac{1}{\left(\frac{\beta h}{2}\right)^3}.$$

The maximum bending stress $f = \frac{M}{Z} = \frac{6M}{t^2}$.

The relationship between f and the shape-factor is shown in *Fig.* 1, in which C_m is the maximum bending stress coefficient such that $f = C_m.\frac{wh^3}{t^2}$ lb. per square inch. *Fig.* 1 is on page 376.

The application of the chart in *Fig.* 1 and the proposed method of calculation is shown in the example which follows.

Example.

Calculate the maximum bending stresses in the wall of a prestressed tank of which the height h is 20 ft., the internal radius R is 50 ft., and the thickness t of the wall is 0·5 ft. Assume $w = 62{\cdot}4$ lb. per cubic foot.

The shape-factor $= \dfrac{h}{\sqrt{Rt}} = \dfrac{20}{\sqrt{50 \times 0{\cdot}5}} = 4.$

From *Fig.* 3, $C_m = 3{\cdot}6 \times 10^{-5}$

$$f = C_m . \frac{wh^3}{t^2} = \frac{3{\cdot}6 \times 10^{-5} \times 62{\cdot}4 \times 20^3}{(0{\cdot}5)^2} = 72 \text{ lb. per square inch.}$$

The effect of partly filling a cylindrical tank is to induce tensile bending stresses in the wall at the face in contact with the liquid. The thickness of the wall must be such that these stresses are not likely to cause cracking of the concrete. A tank which is designed for the full depth of liquid is generally sufficiently strong to resist the effects of partial filling, but if it is certain that a tank cannot be filled above a specified level, economy may result if it is designed for the surface of the contents at this level.

The Quality of British Standard Products.

THE following letter has been received from the Press and Publicity Officer of the British Standards Institution.

"Sir,—All the criticisms which your anonymous correspondent had to say about the British Standards Institution in your August number are in reality an attack on the industries which your journal seeks to serve. For as you know, Sir, the B.S.I. reflects the accumulated knowledge and interests of those members of trade, industry and other specialist authorities who serve on our committees.

It is misleading to quote, out of context, a remark made during a Parliamentary debate. I can assure your readers that the two main speakers in this debate, Mrs. Patricia McLaughlin, M.P., and Mr. John Rodgers (Parliamentary Secretary to the Board of Trade), were highly complimentary of the work of the B.S.I. and of its Kite-mark. Mrs. McLaughlin said that the B.S.I. label was a fair and honest mark but that the B.S.I. needed far more support for the work it was doing. Mr. John Rodgers said that the Kite-mark represented a serious, sustained and, in his own personal view, a wholly praiseworthy attempt to help the consuming public. British Standards were not just minimum standards or a common denominator, but good pass marks indicative of a good, honest product.

Regarding the acceptance by the B.S.I. of responsibility for the quality of the goods on which its Kite-mark appears, every Kite-mark scheme involves careful control over the products which are to be marked. The B.S.I. inspectors visit factories regularly; they test samples in the B.S.I. laboratories (and this is not just prototype testing but continues throughout the life of the Kite-mark product); they buy Kite-marked products on the open market for spot checks.

B.S.I. committees are not composed mainly of representatives of firms making the goods in question. Our committees bring together all the appropriate interests: users, research, organisations, professional institutions and government departments as well as manufacturers' trade associations.

That the Kite-mark really does stand for a satisfactory level of quality is evident from the failure of not a few products submitted to British Standard tests, and the quite extensive modifications and improvements which many firms have to make to their products before they are good enough to qualify for the mark."

Book Reviews.

"Reinforced Concrete Piling and Piled Structures." By F. E. Wentworth-Sheilds, W. S. Gray, and H. W. Evans. (London: Concrete Publications, Ltd. 1960. 149 pages. Price 18*s*. By post 19*s*. In Canada and U.S.A. 4 dollars.)

THE second edition of this book, which was first published in 1938, incorporates so many additions and revisions as to be almost a new book. Mr. H. W. Evans is to be congratulated on the success obtained in bringing up to date the work of the original authors, two well-known engineers who unfortunately are no longer with us. The book is written so as to be easy to follow by engineers and students with little or no experience of the subject, yet contains routine design data and typical calculations for the design of piles, groups of piles, sheet-pile retaining walls, and the estimated safe load on piles as calculated by the Hiley formula. Some mention of the stress-wave theory is also made though sufficient only to assist in preventing piles being damaged during driving.

The book deals at some length with the driving of precast concrete piles, and with bored piles, and includes descriptions of piled structures although this part is restricted to wharves and other marine works. The parts dealing with impact of ships on wharves and jetties and on fendering is up-to-date, although the approach speeds of vessels to be allowed for seems not to take into account the cushioning of the water alongside solid quay walls or to show the advantages of raking piles for absorbing the energy of impact of the ship.

Most reviewers are tempted both to praise and to criticise; so if praise of the good value for the money paid for this book is not enough, but should be qualified, it would only be to ask if the author's use of the term "falling hammer" is because of some objection to the more familiar term "drop hammer."—D.H.L.

"Formwork to Concrete." By C. K. Austin. (London: Cleaver-Hume Press, Ltd. 1960. Price 30*s*.)

THIS is a very practical treatise on an essentially practical subject. The book is very well illustrated as behoves a work dealing with small details, as well as large assemblies of members, in three dimensions. At the outset the author attempts to differentiate the terms formwork (and forms), shuttering (and shutters), moulds, centres and centring (*sic*), but the definitions may not be universally acceptable. The several sound precepts laid down in the introduction seem to be followed in the text. Sufficient theory is given to make the construction of shuttering comprehensible to the students and practical men for whom the book is written.

Most of the structures or structural parts, the shuttering for which is illustrated, are simple although the shuttering itself, such as that for helical stairs, is not so simple. Briefly the contents include the design and construction of shuttering for simple foundations, columns, beam-and-slab floors, curved beams, flat slabs, straight and curved walls, chimneys, cooling towers, dormer roofs, arches and vaults, domes, stairs, balconies and the like, culverts, bridges, and some precast products. Continuously-moving forms are dealt with in some detail. Most of the details are of wooden shuttering but some steel forms and metal scaffolding are described.

"Nature and Properties of Engineering Materials." By Z. D. Jastrzebski. (London: Chapman & Hall, Ltd. 1959. Price 88*s*.)

THE characteristics of materials from their atomic structure to their use in engineering are described in great detail in this American book of more than five hundred pages. A knowledge of general chemistry and physics and of the calculus is necessary to enable the entire text to be understood. The subjects dealt with include the structure of matter, colloids, organic high polymers, phase transformations, mechanical properties, electrical and magnetic properties, thermal properties, corrosion and friction. The materials dealt with include ferrous and non-ferrous metals, ceramics, refractories, glass, inorganic cements (including Portland cement), concrete, and resins, wood, asphalt and other polymeric materials. The section on concrete is concise and sound.

Long-span Prestressed Concrete Floors at Fulham.

THE new research and office building now being constructed at Fulham, London, for the North Thames Gas Board comprises two six-story blocks about 100 ft. high, a two-story block housing computer equipment, an exhibition hall and cinema, and workshops at ground level occupying most of the 3½-acre site. The structure is notable for the extensive use of precast and prestressed concrete and the long span of the floors. The building is on the site of a refilled gravel pit and the foundations are concrete piles. A photograph of a model of the building is shown in *Fig.* 7.

Floors.

It was required that there should be no interior columns. The floors are therefore designed to span the full width of the buildings, 50 ft. in the case of the six-story blocks, and 40 ft., 60 ft., and 62 ft. elsewhere. The floors, which are throughout similar in construction to those in the six-story blocks, are formed of a series of contiguous T-beams of composite construction. The webs and bottom flanges of the beams are precast and prestressed. The top flanges are formed by precast 1-in. slabs (*Figs.* 1 and 2) forming permanent shuttering for the cast-insitu concrete topping, making the floor slab 2½ in. thick at the centre of the span and 3 in. thick at the ends. Welded wire fabric, B.S. Reference No. 113, is embedded in the topping. The overall depth of the floor is 2 ft. and the beams are at intervals of 3 ft. 4 in. providing ample space between the webs for services.

The floors are supported by prestressed concrete edge beams which span between the columns and are of composite construction (*Fig.* 2); the parts below the floor beams were precast and prestressed and erected on temporary steel cleats bolted to the columns. The rest of the beam, up to the level of the top of the floor, was cast insitu when the topping of the floor was placed. Mortar is placed between the ends of the edge beams and the columns, and the shearing forces are resisted partly by stresses induced by prestressing the beams longitudinally along the face of the building. The prestress is produced by means of post-tensioned 1⅛-in. strands which extend the entire length of the building through ducts in the beams and columns and which make the frame continuous.

The weight of a floor of 50 ft. span is about 70 lb. per square foot. The calculated stresses in the floor beams for an imposed load of 110 lb. per square foot are, at release, a tensile stress of 385 lb. per square inch at the top of the beam and a compressive stress of 2990 lb. per square inch at the bottom. The total reduction of prestress is expected to be about 27

Fig. 1.

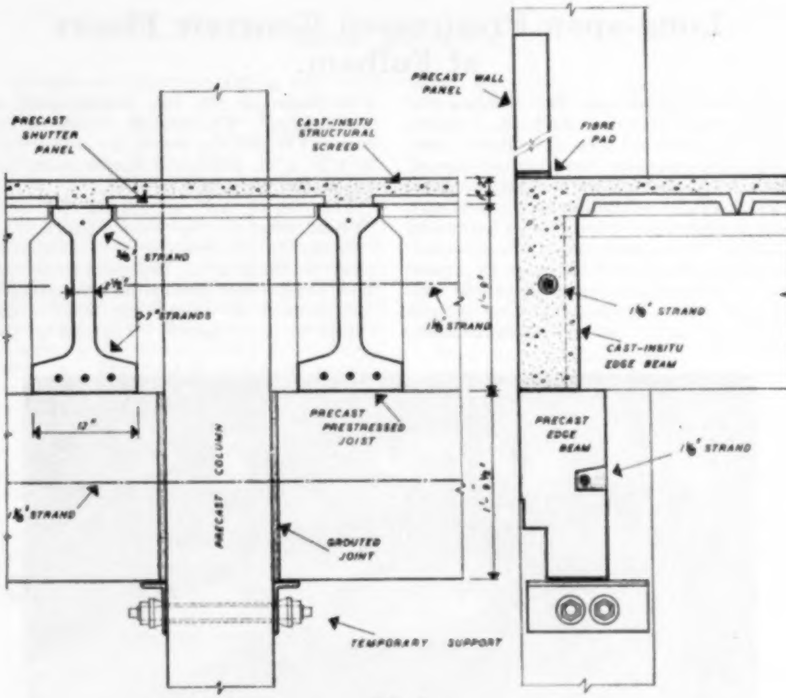


Fig. 2.

per cent. so that under the working load the calculated stresses are a tensile stress of 255 lb. per square inch at the bottom and a compressive stress of 1530 lb. per square inch at the top of the precast beam and 975 lb. per square inch in the cast-insitu topping.

Frame.

The pressure of the wind on the tall structures is resisted by diagonal bracing in the end frames and by the lift-wells and stair-wells which are cast insitu. The floors are considered to act as horizontal beams transferring the wind forces to the braced frames and lift-wells. Longitudinal rigidity is also provided by the walls beneath the windows of each story, although no account is taken of this in the design calculations. The panels of the walls were precast and reinforcing bars projecting from the ends of the panels

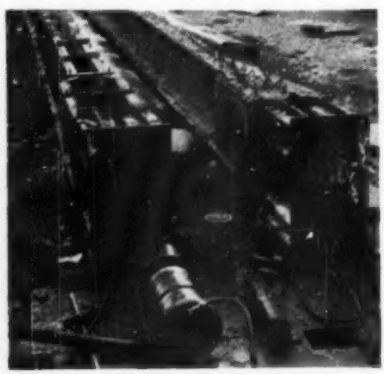


Fig. 3.

overlap bars projecting horizontally from the columns. Concrete is placed around the bars to make the walls monolithic with the columns. The walls are not connected to the floors at edge beams.

The reinforced concrete columns were precast generally in lengths equal to the height of one story. Vertical ducts were formed in the lower part of each column so that when the column was lowered into position bars, protruding from the column or column base below, entered the ducts for a distance equal to the bond length of the bar. Cement grout pumped into the ducts provides continuity between the upper and lower columns.

Concrete.

The concrete for all the prestressed members is made with high-alumina cement. The mixture is determined by the quality required but is about 1 : 2 : 6½. A low proportion of cement to aggregate is used so that the effects of creep and shrinking are as small as possible. The crushing strength of the concrete is required to be 7500 lb. per square inch at transfer, which takes place about seventeen hours after placing the concrete and 9000 lb. per square inch at twenty-eight days. Rapid-hardening cement is used for the precast columns, the 1-in. precast slabs and all cast-insitu concrete, and the crushing strength at twenty-eight days is required to be at least 6000 lb. per square inch. The crushing strength of the concrete of the walls is required to be at least 3000 lb. per square inch at twenty-eight days.

Fig. 4.

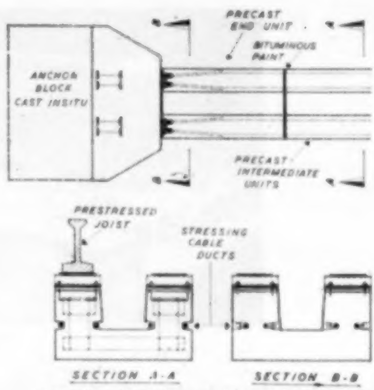


Fig. 5.—Details of Prestressing Beds.

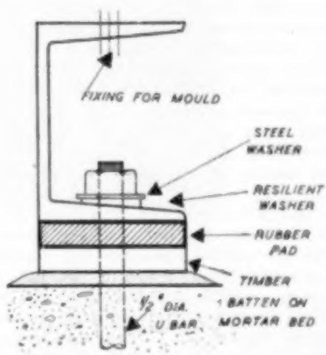


Fig. 6.—Fixing for Moulds.

The tolerances allowed were plus or minus ¼ in. in the length of the precast members, plus or minus ¼ in. in the lateral dimensions, and plus or minus ¼ in. in the position of the prestressing steel. Since most of the connections between the members are of cast-insitu concrete it was the practice for dimensions on drawings to be less, by the permissible tolerance, than the full length required.

The columns, edge-beams, wall panels, and 1-in. slabs were precast at a factory.

Prestressed Beams.

The prestressed beams for the floors were made on the site by the long-line

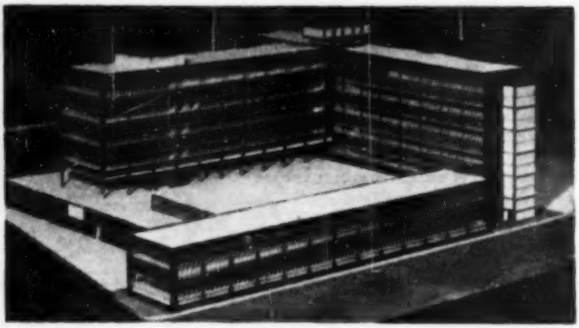


Fig. 7.

method on two double prestressing beds (*Fig.* 3) each about 220 ft. long. The beds are formed of a number of concrete blocks each about 8 ft. long which are placed end to end and prestressed (*Fig.* 4). Each block weighs about 4 tons so that the beds can be dismantled and removed to another site. The prestressing cables each contain twelve 0·276-in. wires and extend from end to end of the beds in grooves (*Fig.* 5) and are anchored in cast-insitu blocks at the ends of the beds.

The steel shutters for the beams are fixed to a bed by bolts projecting vertically from the bed. Rubber pads and wooden blocks are placed between the shutters and the bed (*Figs.* 5 and 6) so that the vibrators, which are attached to the shutters, transmit the minimum amount of energy to the bed. The best position for the vibrators on the long shutters was the subject of experiment.

The beams are prestressed with pre-tensioned strands which are stretched by means of the hydraulic jacks shown in *Fig.* 3. Three strands of 0·7 in. nominal diameter at the bottom of each beam were each stretched with an initial tension of 53,400 lb.; one ⅜-in. strand at the top was subjected to an initial tension of 14,700 lb.

Each beam weighs about 2½ tons and, when hardened, is transferred to the stockyard by one of two tower cranes.

The cost of the concrete structure is about 145 shillings per square yard of the floor area and it is estimated that the total cost of the concrete structure is about £60,000 less than the cost of a similar steel structure with concrete cladding.

The architects and consulting engineers are Messrs. E. R. Collister and Associates, and the general contractors are Messrs. Trollope and Colls, Ltd.

Pierhead, Ltd., are responsible for the design and construction of the concrete frame and floors. The anchors for the strands and the jacks for the edge beams were supplied by Cable Covers, Ltd. The anchors for the cables and the jacks used on the casting bed were of the Gifford-Udall type. P.S.C. jacks were used for the floor beams.

The Terminology of Prestressed Concrete.

A CORRESPONDENT writes:

In his letter published in your July number, Mr. A. J. Harris agrees with you that the terms pre-tensioned and post-tensioned concrete are misleading and should not be used. He prefers pre-tensioned prestressed concrete (and presumably post-tensioned prestressed concrete). This term contains two adjectives. Prestressed is not sufficient because it does not indicate the kind of stress to which the concrete (or the steel) has been subjected, nor does it indicate whether the steel was stressed before or after the concrete had hardened. The other adjective is pre-tensioned (and presumably post-tensioned), indicating that the concrete is tensioned. This is the opposite of the truth, for prestressed concrete is subjected to a compressive force only, which as a by-product produces unwanted small tensile and other stresses.

Prestressed Concrete Sewage Tanks of Unusual Shape.

THE shape of two sewage tanks (*Fig.* 1) at Schweinfurt, Germany, which are described recently in " Beton- und Stahlbetonbau ", has structural advantages and characteristics suitable for the flow of the contents. Each tank is 23 m. high (75 ft. 6 in.) and the greatest diameter is 16 m. (52 ft. 6 in.). The capacity of each is 2500 cu. m. (88,000 cu. ft.). The thickness of the wall varies from 25 cm. (10 in.) at the sides to 80 cm. (2 ft. 7 in.) at the base, and is such that bending moments in the vertical direction can be resisted without prestressing vertically.

The main structural parts (*Fig.* 2) include a ring foundation (A), the base-cone (B), and bearing-ring (C), the wall (D), the top ring-beam (E), the top-cone (F), and the parapet (G). The wall and top ring-beam are prestressed circumferentially. The parapet, which is in reinforced blockwork, encloses the valves and pipes, and was neglected in the structural analysis of the main tank. The pipes to the central machine-house are in a cantilevered duct at the top and in the cellar.

Fig. 1.

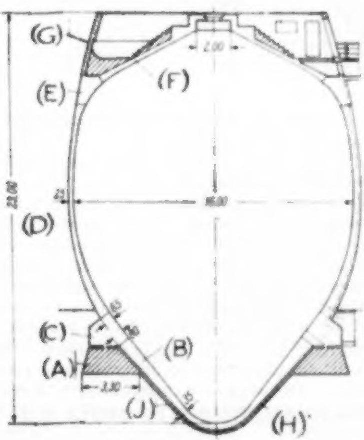


Fig. 2.

The forces and bending moments on the structure are shown in *Fig.* 3, in which the circumferential forces and bending moments due to the prestress are given at (a) and (b) respectively, and the circumferential forces and bending moments due to the contents of the vessel are given at (c) and (d) respectively. The forces and moments are in metric units. The expansion gap, 4 cm. (1½ in.)

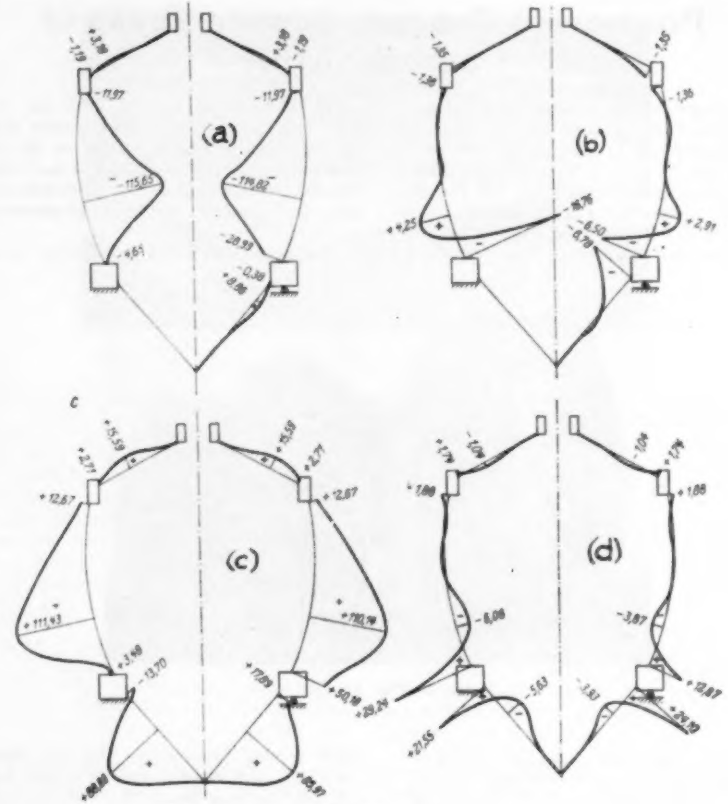


Fig. 3.

wide, which is shown at (H) in *Fig.* 2, between the base-cone and the blinding concrete (J) is filled with a yielding material which also provides thermal insulation. The connection between the bearing-ring and the foundation is a hinge.

The walls were analysed as frustums of conical shells for two probable extreme conditions of support, namely (1) if the bearing-ring be held rigidly; and (2) if the bearing-ring be free to slide and rotate upon the foundation. The actual condition is between these extremes, but sufficient reinforcement is provided to resist the most adverse effects. The diagrams on the left-hand side of each centre-line in *Fig.* 3a, b, c and d are for condition (1) and those on the right-hand side are for condition (2).

Each circumferential prestressing cable comprises ten ribbed oval wires, 4·2 mm. by 9 mm. (0·16 in. by 0·35 in.). A prestress greater than that necessary to counteract the hydrostatic pressure was applied, thereby reducing the vertical bending moments and the variation of stress as the tank is filled. Each cable, which is of the Siebert-Stinnes HG type, encircles the tank, and was jacked from each end and from an intermediate position. The sequence of stressing was such that the prestress was practically uniform throughout. A small recess is formed at each intermediate jacking position; additional reinforcing mesh is provided in

the inner wall at each recess. The ducts and recesses were grouted after stressing.

The base-cone and bearing-ring were concreted monolithically. The walls were built in three sections, with joints at the stressing positions. Copper water-bars are provided in each joint. The outer shuttering was erected for the entire height of the wall but the inner shuttering was built up as concreting proceeded in lifts of 1·5 m. (5 ft.).

A vapour barrier and sheets of cork are applied to the outer face of the concrete vessel, and the structure is faced with sheets of aluminium attached to wooden battens. Wooden laths and vertical ribs are fixed over them.

FIFTY YEARS AGO.

From "CONCRETE AND CONSTRUCTIONAL ENGINEERING", October, 1910.

The History and Development of Reinforced Concrete.

THE following extract is from a lecture by MR. H. KEMPTON DYSON.

"It is only within about the last twelve years that reinforced concrete as a method of construction has come into prominence. The subject, however, is not entirely new. The Romans and others reinforced concrete by bronze rods, timber and tiles.

"The first suggestion of an idea of reinforcing concrete, in modern times, seems to have been a statement in J. C. Loudon's 'Encyclopædia of Cottage, Farm and Village Architecture', published in 1830, in which it was suggested that flat roofs might be constructed of a latticework of iron tie rods thickly embedded in cement and cased with flat tiles. In 1840, about, two systems of floor construction were employed in Paris, known as the Vaux and Thuasné systems; the former consisted of round rods, closely spaced, hooked over flat wrought-iron bars placed on edge some distance apart, and embedded in a slab of plaster of Paris concrete; while the latter employed small iron joists, with hangers or stirrups placed over them in which round rods were suspended, placed in holes in the stirrups. Plaster of Paris was, however, not a proper cement to be employed, as it caused the embedded iron to rust, and probably the reason reinforced concrete did not arrive sooner was that the world was waiting for a suitable cement for making concrete—it needed Portland cement, which was invented in 1824.

"The first real inventor of reinforced concrete in the modern sense seems to have been W. B. Wilkinson, a plasterer, of Newcastle-on-Tyne, who took out a patent in 1855 for reinforcing slabs with a network of iron rods, and a M. Lambot, another French contractor, proposed the construction of ships by means of concrete, with an embedded skeleton of wire, and he constructed a punt of the kind which was shown at the Paris Exhibition of 1853, and is still in service in a pond at Miraval, where he resided. The development of the subject was extended by the following inventors: C. C. Dennett (1857); Matthew Allen (1862); Frederick Ransome (1865); H. Y. D. Scott (1867); Philip Brannon (1870), who first suggested the driving of reinforced concrete piles; Monier (1867–1873); Thaddeus Hyatt (1873–1877), who conducted a great many tests on reinforced concrete beams and showed how to make calculations for determining their strength; W. E. Ward (1875); W. H. Lascelles (1877); H. J. Jackson (1877); E. L. Ransome (1884); J. C. Golding (1884); W. H. Lindsay (1885); William Simmons (1885–1886), who designed the block of offices, No. 63, Lincoln's Inn Fields, London, which, constructed of reinforced concrete, is still in use and in excellent condition;* Lee & Hodgson (1885), who invented a spirally reinforced concrete column; Bordenave (1887); Cottançin (1884); W. H. Briggs (1889); J. Mayoh (1890); A. J. B. Ward (1891); C. A. Day (1891); Franz P. Meyenberg (1891), who introduced the first loose stirrups in beams; F. G. Edwards (1891); P. Stuart (1892); Koenen and Wayss (1892); François Hennebique (1892). There are over seventy systems upon the market in Europe and America to-day."

* [This building, which was visited in September 1960, is still in good condition.—ED.]

Strength of Concrete Containing Pulverised-fuel Ash.

MANY tests made in the U.S.A. have shown that if Portland cement is replaced with an equal volume of pulverised-fuel ash the strength of the resulting concrete is much reduced at early ages, although at an age of six months and later the strength may be the same as that of concrete in which the cement has not been diluted with pulverised-fuel ash. Because it is generally necessary to specify a strength at an age of 28 days or earlier, Mr. C. E. Lovewell and Mr. George W. Washa have made some extensive tests at the University of Wisconsin on the production of concrete in which part of the cement content has been replaced with pulverised-fuel ash and which will have at early ages the same strength as concrete made with undiluted cement.

Some of the results of tests of concrete in which some part of the cement was replaced with pulverised-fuel ash are compared with concretes in which the cement was undiluted are as follows. In all cases graded aggregate of ¾ in. maximum size was used. Compressive strengths are in pounds per square inch.

376 lb. of cement per cubic yard: at 1 day, 273 lb.; at 3 days, 786 lb.; at 28 days, 2470 lb.—94 lb. of cement omitted and replaced with 175 lb. of pulverised-fuel ash: at 1 day, 266 lb.; at 3 days, 886 lb.; at 28 days, 3135 lb.

423 lb. of cement per cubic yard: at 1 day, 355 lb.; 3 days, 1020 lb.; 28 days, 3090 lb.—85 lb. of cement omitted and replaced with 156 lb. of pulverised-fuel ash: at 1 day, 314 lb.; 3 days, 1080 lb.; 28 days, 3425 lb.

470 lb. of cement per cubic yard: at 1 day, 482 lb.; 3 days, 1305 lb.; 28 days, 3750 lb.—82 lb. of cement omitted and replaced with 137 lb. of pulverised-fuel ash: at 1 day, 370 lb.; 3 days, 1345 lb.; 28 days, 3720 lb.

517 lb. of cement per cubic yard: at 1 day, 572 lb.; 3 days, 1595 lb.; 28 days, 4055 lb.—77 lb. of cement omitted and replaced with 118 lb. of pulverised-fuel ash: at 1 day, 417 lb.; 3 days, 1605 lb.; 28 days, 4015 lb.

564 lb. of cement per cubic yard: at 1 day, 716 lb.; 3 days, 1910 lb.; 28 days 4835 lb.—70 lb. of cement omitted and replaced with 100 lb. of pulverised-fuel ash: at 1 day, 499 lb.; 3 days, 1870 lb.; 28 days, 4190 lb.

It is seen that the strengths of the normal mixtures and those containing pulverised-fuel ash do not differ greatly at ages up to 28 days so long as the amount of cement omitted is not more than 20 to 25 per cent. and is replaced with a greater weight of pulverised-fuel ash. The specimens containing pulverised-fuel ash were slightly denser than those without, but the densities of all the specimens were between 150 lb. and 152½ lb. per cubic foot. In the specimens containing pulverised-fuel ash the proportion of coarser aggregate was slightly reduced and the proportion of finer aggregate increased. The quantity of mixing water was also less in the case of the specimens containing pulverised-fuel ash; the ratio of water to cement plus ash (by weight) was 0·54 in the mixture with least cement and 0·45 in the richest mixture.

The leaner the mixture the greater the replacement of cement by ash; in the case of the leanest mixture the cement omitted was replaced by about twice its weight of pulverised-fuel ash.

It is reported that at ages later than 28 days concrete containing a proportion of pulverised-fuel ash replacing a proportion of cement has exceeded the strength of concrete in which none of the cement has been replaced by ash.

The general conclusions reached are as follows:

(1) In order to obtain similar compressive strengths at ages between three and twenty-eight days, mixtures made with pulverised-fuel ash must have a total weight of Portland cement and pulverised-fuel ash greater than the weight of the cement used in the comparable normal Portland cement mixtures. The normal mixtures will, however, contain from 70 lb. to 94 lb. more cement per cubic yard of concrete.

(2) The maximum amount of pulverised-fuel ash should be used with lean concretes. With the materials used in the tests, 175 lb. of pulverised-fuel ash was used to replace 94 lb. of cement per cubic yard of concrete in a nominal mixture

containing 376 lb. of cement, while 100 lb. of pulverised-fuel ash was used to replaced 70 lb. of cement per cubic yard of concrete in a nominal mixture containing 564 lb. of cement. The actual amounts vary with the type of pulverised-fuel ash and aggregates used as well as with the richness of the mixture.

(3) The ratios of sand to total aggregate for mixtures made with pulverised-fuel ash should be reduced 0·02 to 0·04 below those used in comparable normal Portland cement mixtures having equal early compressive strengths.

(4) With relatively few check tests, proportions for concrete containing a given pulverised-fuel ash and given aggregates can be arranged that will give results which may be predicted with reasonable accuracy.

Shearing Stresses in Prestressed Concrete Beams.

In our Editorial Notes (for February 1960) dealing with the British Standard Code of Practice No. 115 (1960), "The Structural Use of Prestressed Concrete in Buildings", comment was made on the absence of any recommendation relating to the maximum shearing stress to which prestressed concrete beams should be subjected. An explanation of this omission is given by Dr. P. Abeles, who writes as follows.

"In ordinary reinforced concrete, the resistance to shearing force is based on conditions under the working load and two limiting shearing stresses are generally recommended. (1) A maximum permissible stress if no reinforcement to resist shearing is provided, this stress being sufficiently low that cracks are not likely to form. (2) A higher maximum stress which is permissible if there is sufficient reinforcement to resist the whole of the shearing force; this limit is necessary to prevent the development of wide cracks under working load, since cracking is likely to occur if the lower permissible stress is exceeded. The amount of reinforcement provided ensures automatically that there is sufficient safety against failure in shearing.

Two conditions apply to the design of prestressed concrete, that is at working load and at ultimate load. For the former condition, there is complete freedom from cracking since the principal tensile stress is limited, and therefore the behaviour under working load is better than in the case of ordinary reinforced concrete. Under ultimate load, all the shearing force to which a prestressed concrete beam is subjected is resisted by reinforcement as in a reinforced concrete beam. The widths of the cracks at ultimate load are immaterial, and therefore the shearing stress (at ultimate load) is also of no consequence."

A Marine Road 17½ miles Long.

It was announced recently in Engineering News-Record that work is about to commence on the construction of a road 17½ miles long from Delmarva Peninsula to Norfolk across the lower Chesapeake Bay, U.S.A. The crossing will comprise about twelve miles of trestle construction, two tunnels, two bridges, and an earthen causeway on a natural island. The trestles will be founded on 54-in. diameter hollow concrete piles up to 130 ft. long which will be precast in lengths of 16 ft. and prestressed. When in position the piles will be filled with sand. A precast capping beam will be placed on the groups of piles; there are generally three piles for each trestle. The capping beam will support tie-beams 75 ft. long, 4 ft. deep, and prestressed with $\frac{7}{16}$-in. strand. The 28-ft. road will be laid on these beams.

The two tunnels will be precast in parts 200 ft. long which will be sunk in prepared channels and covered with earth. The ends of each tunnel will be on artificial islands about 30 ft. above mean low water. One tunnel will be 5738 ft. long and 72 ft. below mean low water at its lowest point. The other will be 5450 ft. long and 50 ft. deep at its lowest point. The outside dimensions of the tunnels are 37 ft. by 37 ft.

The bridges will be of steel-girder construction, one being 1356 ft. long and the other 3795 ft. long. The former bridge will have a central navigation span of 110 ft. with a vertical clearance of 40 ft., and will be supported on piles similar to those for the trestles. The longer bridge will have a central navigation span of 300 ft. and a vertical clearance of 75 ft.

An Open-air Theatre with a Concrete Canopy.

THE open-air theatre recently completed in Bishop's Park, Fulham, has a reinforced concrete canopy and roof (*Fig.* 1). The canopy, which cantilevers a distance of 25 ft. at an angle of 22 deg. from the horizontal, is 40 ft. wide and 14 in. thick at the supporting proscenium beam, and 65 ft. wide and 4 in. thick at the outer edge. A smooth surface was required to the soffit without the need to render, plaster or paint the concrete. Blocks or spacers to support the reinforcement were not therefore used since they would impair the appearance of the surface. Hardwood bearers were placed beneath the reinforcement and drawn upwards as concreting proceeded. It was originally intended that the reinforcing bars for the canopy should radiate outwards from a 3-in. pitch at the support to a 5-in. pitch at the outer edge, but this arrangement altered to a pitch of 2 in. and 4 in. alternately allowed easier manipulation of immersion vibrators. The shutter boards were of $\frac{5}{8}$-in. plywood cut to a radiating pattern and fixed by wrought boards screwed to the underside.

Fig. 1.

The concrete mixture was based on nominal 1 : $1\frac{1}{2}$: 3 volumetric proportions and had to be stiff enough to be placed on a slope of 22 deg. without top shutters. A light coloured concrete was provided by using Portland cement and the lightest coloured aggregate obtainable from a local source; crushed Portland stone was prohibited by its cost. The strength of the test cubes at fourteen days was approximately 5850 lb. per square inch and the shuttering was removed after three weeks, by which time the strength was estimated to be 6720 lb. per square inch. In order that the concrete could be placed without ceasing work concreting was continued through the night. The concrete was deposited on the shutters and spread steadily up the incline and then compacted by vibrator. This operation was done in 2-ft. strips working across the roof, thereby ensuring that the concrete in one strip had initially set before the strip above it was commenced. The surface of the concrete was screeded and finished off by a trowel. The shuttering was removed by lowering the props on

jacks and consequently lowering the complete shuttering in one operation. Immediately after removal of the shuttering a loading test was made; thirty men walked up the incline and stood at the outer edge. The deflection was $\frac{1}{16}$ in. compared with the calculated deflection of 1 in.

The proscenium opening is 32 ft. 6 in. wide and 12 ft. 9 in. high. The forestage depth is 14 ft. extending to a maximum depth of 16 ft. The total weight of the main roof is 120 tons. Electrically operated sliding doors shut off the stage and are suspended from the proscenium beam. The structural frame consists of four columns supported on spread footings. The roof and canopy are virtually balanced on the two columns supporting the proscenium beam. The walls are of brick infilling. The small flights of steps (*Fig.* 2) leading to the stage and to the dressing rooms at the rear of the building are of reinforced concrete. The wings of the stage are decorated with black marble slabs and precast concrete "Mineralite" slabs.

Fig. 2.

The theatre was designed by the architect of the Borough of Fulham, Mr. E. A. H. MacDonald, A.R.I.B.A. The consulting structural engineers were Messrs. J. H. Coombs & Partners. The contrators were Messrs. W. J. Marston & Son.

Economical Construction of a School.

A SCHOOL recently completed at Stamford, Lincolnshire, is claimed to have been constructed economically despite the high standard of the materials used. The building accommodates three hundred children and occupies a well-drained ten-acre site. The main frames, floors and roofs are of reinforced concrete which was cast in place. The main teaching block and entrance hall is a two-story structure; the adjoining assembly hall, gymnasium, and administrative areas are of one story. The frames for the gymnasium and assembly hall are at 13-ft. 4-in. centres and each comprises four members and spans 36 ft. 6 in.; the roof, which has a slope of 10 deg., is covered with $5\frac{1}{2}$-in. hollow-tile slabs. Two-story rectangular frames spanning 24 ft. 9 in. are incorporated in the main teaching block at 10-ft. centres and have haunched beams at the roof and first floor. The roof and floor slabs are $4\frac{1}{2}$ in. thick and of the hollow-tile construction. Cantilevered construction provides the stair landing and entrance to the classrooms at the first floor, and supports the main stairs. An expansion joint is provided between the balcony overlooking the main assembly hall and the top step of the stairs. The two flights of stairs in the main entrance hall are supported on a mushroom-shaped column. Concrete for the frames is $1 : 1\frac{1}{2} : 3$ and was compacted by immersion vibrators. Concrete for the roof and floor slabs is $1 : 2 : 4$.

The exterior cladding is of local hand-made facing bricks and mahogany weather-boarding. Wooden blocks are provided on the floors of the teaching areas, and rubber, p.v.c. and linoleum are used in the circulation areas. The roofs are covered with copper sheeting and three-ply felt. The net cost was £3 9*s*. 6*d*. per square foot. The major part of the school was completed within sixteen months.

The architect is Mr. Edward Craven, A.R.I.B.A., and the general contractors Messrs. Stirton Partners, Ltd. The reinforced concrete work was designed and constructed by The Kleine Company, Ltd.

A Large Ready-mixed Concrete Plant in London.

ONE of the largest ready-mixed concrete plants in the country and probably the largest in the London area commenced production recently. The plant (*Fig.* 1), which is on the Thameside at Fulham, is capable of producing 1500 cu. yd. per day. The plant is mainly automatic and requires only three operators. The batching of materials can be controlled to accuracies of ½ per cent., and the plant is able to deal rapidly with six varieties of aggregate and three types of cement simultaneously. The position of a laboratory at the works enables tests to be made regularly on the materials and concrete.

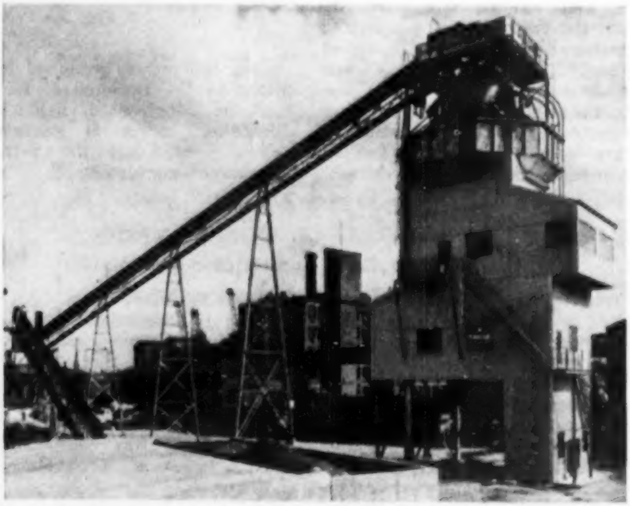


Fig. 1.

At present the materials are delivered by road but later there will be facilities for railway and river transport. The aggregates are obtained from pits in west Middlesex and are discharged from lorries on a concrete ramp into four bunkers, each of 50-cu. yd. capacity, at ground level. The aggregates are carried from the bunkers to the bins in the batching and mixing tower by means of a two-stage system of conveyors. The material is fed on to the lower conveyor through remotely-controlled gates. The first stage of the conveyor is 220 ft. long and is inclined at an angle of 19 deg.; the second is 170 ft. long and inclined at an angle of 18 deg. The system is devised to prevent the lower conveyor operating before the upper, and when one conveyor stops the other is automatically cut out. The material makes the 85-ft. ascent at the average rate of 260 ft. per minute and can be fed into the bins at a rate of 150 cu. yd. per hour by means of a pivoted distributor from which the aggregate travels down a chute into the compartment desired. There are nine bins having a total capacity of 300 cu. yd. Six bins are used for aggregates and three for cement. The cement is fed pneumatically from pressurised tank vehicles directly into the bins at the top of the tower. Water is pumped from a main storage tank at ground level up to a 400-gallon tank in the tower.

One man only is needed to control the supply of materials from the bunkers or vehicles to the bins. The other two men control the batching and mixing operations. A group of dials in the control room at the base of the tower indicates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the quantities in each of the bins and it is from here that the operator controls the conveyor.

The constituents for the concrete are weighed in four hoppers. The cement hopper is fitted with a pre-set automatic cut-out and that for the sand incorporates a moisture meter which registers on the control panel. From the hoppers the aggregates are discharged through radial gates and the cement and water through semi-rotary valves, all of which are worked by pneumatic rams. The materials can be fed into a 4-cu. yd. tilting-drum mixer, or, without the water, they can be fed dry directly into a truck-mixer or a tipping lorry. The drum-mixer is driven electrically and tilted by a pair of hydraulic arms. The mixing time is pre-set and the mixer-drum cannot be tilted for discharge before the stipulated time has elapsed.

Deliveries of mixed concrete are made in 3-cu. yd. agitators on lorries which are in contact by radio with the plant, thus enabling the Company to keep the customer informed on the whereabouts of his consignment. This means of transport is to be supplemented later by truck-mixers of 6-cu. yd. capacity.

The plant was supplied and erected by Winget, Ltd., for Greenham Ready-Mixed Concrete, Ltd. The concrete is supplied under the name of "Fulcrete".

Lectures on Building.

THE following lectures have been arranged by the Ministry of Works. Admission is free.

Thermal Insulation of Buildings. By J. Lawrie. Technical Institute, Southway, Bognor Regis, October 18, 7.15 p.m.; and by R. R. Houston, Town Hall, Worthing, October 28, 7.15 p.m.

Practical Formwork Design and Construction for Concrete. By J. G. Richardson, at the Technical College, Coventry, October 18, 7.15 p.m.; North Oxfordshire Technical College and School of Art, Bath Road, Banbury, October 20, 7.15 p.m.; George Hotel, Luton, October 25, 7.15 p.m.; and Queen's Building, University of Bristol, Bristol, October 27, 6 p.m.

The R.I.B.A. Form of Contract. By D. Gardam. Lyceum Club, Bold Street, Liverpool, October 25, 6.15 p.m.

The R.I.B.A. Form of Contract—Part II. By I. N. D. Wallace. Technical College, Waterdale, Doncaster, October 18, 7.15 p.m.

Structural Properties of Lightweight-aggregate Concrete. By G. H. Newton. Mackworth Hotel, Swansea, October 18, 7 p.m.

Operational Research in Buildings. By J. F. Nuttall. Royal Society Hall, George Street, Edinburgh, October 25, 7.15 p.m.; and Scottish Building Centre, Sauchiehall Street, Glasgow, October 26, 7.15 p.m.

The Settlement of Buildings. By S. R. Rosenack. Nottingham Technical College, Burton Street, Nottingham, October 26, 7.15 p.m.

Prestressed Concrete. By H. Kaylor. Sun Hotel, High Street, Chatham, October 27, 7.15 p.m.

Surface Finishes of Concrete. By F. Ward. Hertfordshire College of Building, Hatfield Road, St. Albans, October 27, 7.15 p.m.

The Reinforced Concrete Association.

THE subjects of the meetings of the Reinforced Concrete Association to be held at 11 Upper Belgrave Street, London, S.W.1 during 1960 are as follows.

October 19.—"Lift Slab Design and Construction." By F. R. Benson.

November 16.—"The Code of Practice for Prestressed Concrete." By A. W. Hill.

December 1.—"Reinforced Concrete Construction in the Coal Industry." By C. A. C. Davies.

Particulars of meetings to be held in Manchester, Liverpool, Birmingham and elsewhere can be obtained from the Secretary, 94 Petty France, London, S.W.1.

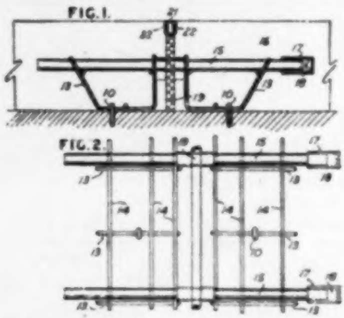
A Prestressing System.

PRESTRESSED SALES LTD. announce that the system of prestressing by means of strands which was previously supplied under the name of Udall has now been renamed the Gifford-Burrow system.

Patent Applications.

Expansion Joints for Roads.

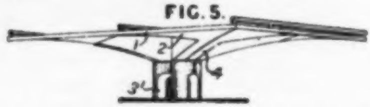
An expansion joint for a concrete road is positioned before the concrete is laid by supporting the joint filler upon horizontal dowels carried upon frameworks located at each side of the joint. As shown, the chairs (13), formed of bent steel bars, are fixed to the foundation of the road by spikes (10) and held together by tie-bars (14). Dowels (15), which are welded to the tie-bars and pass through holes in the joint filler (19), comprising impregnated



insulation board or softwood, are coated with a bitumen preparation over half of their length to prevent bonding to the concrete (16) and are provided with cardboard caps (17) containing a compressible filling (18) to allow movement of the dowel (15) relative to the cap. Before the concrete has completely hardened, a groove is cut above the joint filler (19) to accommodate the joint sealer (21) in the form of a rectangular rubber or plastic tube having external fins (22) on opposite sides.—No. 819,600. British Reinforced Concrete Engineering Co., Ltd. January 7, 1958.

Bridges and Elevated Roads.

An elevated roadway is made up of square concrete sections each mounted on a central pillar from which diagonal rib-like girders project, the thickness of the section and supporting girders increasing from the edges to the centre of the section. As shown, the square concrete slab 1 containing axial and transverse tensioned reinforcements, has strengthening portions 2 and ribs 4 both of which increase in thickness from the edge of the section towards the central supporting pillar 3^1 which may be solid or hollow as shown. In a modification, two independent rectangular sections are arranged side by



side to accommodate streams of traffic in opposite directions, and each section, supported on a central pillar, increases in thickness from its edges to the centre; two supporting ribs extend from the central pillar parallel to the sides of the section.—No. 827,936. E. Lubbert, E. Schulz, U. Finsterwalder, R. Jecht, and E. Ruf. October 31, 1957.

Concrete Surface Improved with Plastics.

A concrete with an improved surface contains solid pellets of a thermoplastic resin and may be produced either by moistening a mixture of cement and pellets and allowing to harden or by embedding the pellets in a moist cement surface. The cement may be any hydraulic cement, for example, Portland, aluminous, or white cement, or plaster of paris, and the pellets, which comprise 25 per cent. to 75 per cent. by volume of the concrete, may be a polymer or copolymer of styrene, polyvinylchloride, methyl polyacrylate, or polyethylene. Water may be used to moisten the composition, but when the pellets comprise polystyrene, toughened preferably by incorporating rubber in it, an aqueous dispersion containing a styrene polymer and a plasticiser and stabiliser by a protective colloid, for example, casein, or a non-ionic dispersing agent, or both, may be employed. Fillers, for example, sand, crushed granite, brick dust, wood flour, or granulated cork, may be included in the compositions.—No. 826,582. Monsanto Chemicals, Ltd. April 1, 1958.

MISCELLANEOUS ADVERTISEMENTS.

Situations Wanted, 5d. a word: minimum, 12s. Situations Vacant, 6d. a word: minimum, 15s. Other miscellaneous advertisements, 6d. a word: minimum, 15s. Displayed advertisements, 40s. per column inch. Box number 1s. extra.

Advertisements must reach this office, 14 Dartmouth Street, London, S.W.1, by the 26th of the month preceding publication.

SITUATIONS VACANT.

SITUATIONS VACANT. Designer/engineer with at least five years' experience in reinforced concrete, structural steel and general building construction. The work is varied and offers scope to take responsibility for projects, but does not involve working outside London except for site visits. A vacancy also exists for an assistant engineer with three years' experience as above. Write, stating age, experience, and salary required, to Donovan H. Lee & Partners, Consulting Engineers, 66 Victoria Street, London, S.W.1.

SITUATION VACANT. D. W. Cooper requires designer-draughtsman experienced in reinforced concrete work and/or steelwork, and/or timber engineering. Apply, in writing, stating age, qualifications and marital status, to 165 Westmorland Road, Newcastle-upon-Tyne, 4.

SITUATIONS VACANT. Consulting engineers have vacancies for the following: Reinforced concrete designers with A.M.I.Struct.E.; Designer-detailers with H.N.C. or similar; Detailers with minimum two years' experience. The positions are permanent, with opportunity for advancement. Modern office and pleasant conditions. Salaries in accordance with experience. Bylander, Waddell & Partners, 169 Wembley Park Drive, Wembley.

SITUATION VACANT. Consulting engineers in Westminster require engineer to take charge of site investigations and soil mechanics laboratory. The post offers scope for a well-qualified, energetic man. Full details to Box 4701, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Supervisor required for part of large precast concrete works producing a variety of products. Previous experience of handling and organising labour essential. Salary £1000 per annum. Apply, in writing, with full details, to Works Manager, Tarmac Vinculum Ltd., Bilston Lane, Willenhall, Staffs.

SITUATIONS VACANT. Capable engineering assistants required by Consulting Engineers in London office. Varied and interesting work on reinforced concrete and steel structures and foundation work for projects at home and oversea. 5-days' week. Luncheon vouchers. Apply, Maurice Nachshen & Partners, 58 Victoria Street, London, S.W.1.

SITUATION VACANT. Draughtsman required for a newly-formed Research & Development Department by Civil Engineering Contractors. Experience and interest essential. Excellent prospects, salary, bonus and pension scheme. Applications in writing, stating age, experience and salary required, to: West's Piling & Construction Co. Ltd., Bath Road, Harmondsworth, Middx.

SITUATIONS VACANT. A vacancy exists for a reinforced concrete designer or an experienced designer-detailer and for an experienced detailer draughtsman. Good prospects. Varied and interesting work. Luncheon vouchers. 5-days' week. Apply, with particulars of experience and salary required, to John F. Farquharson & Partners, 34 Queen Anne Street, London, W.1.

SITUATIONS VACANT. Edward A. Pitcher & Partners require experienced engineer/section leader for reinforced concrete department. Commencing salary up to £1600 per annum according to experience and qualifications. Reinforced concrete designers and detailers also required. Good salaries and prospects. 14 Queenhithe, London, E.C.4. Central 9881.

SITUATIONS VACANT. Reinforced concrete designers-contractors, established 60 years, require designer-detailers for interesting work in modern Manchester office, to work in a small team under qualified engineers. Good salary and scope for advancement, five-days' week, pension scheme. Apply Fram Reinforced Concrete Co. Ltd., 165 Plymouth Grove, Manchester, 13. Telephone Ardwick 4521.

SITUATIONS VACANT. Clarke, Nicholls & Marcel require for their new Bristol offices designers, detailers and draughtsmen, experienced in reinforced concrete. Excellent opportunities in an expanding organisation. Positions are pensionable, and offer first-class experience for those studying for professional qualifications. Apply, in writing, to 10 Apsley Road, Clifton, Bristol, 8.

SITUATIONS VACANT. Reinforced concrete detailers required by Leonard & Grant in their South London drawing offices. Only top men should apply. High salaries. Interview by appointment. Telephone Tate Gallery 8496.

SITUATIONS VACANT. Consulting engineers require in their London office experienced reinforced concrete designers and designer/detailers. Also experienced detailers willing to learn design. Five-days' week. Good salaries for the right people. Apply, in writing, to S. Zukas, Chief Engineer, John De Bremaeker & Partners, 3 Southampton Place, London, W.C.1.

SITUATION VACANT. Consulting engineers have vacancy for Engineer with working knowledge of soil mechanics practice and its application to all types of foundation design. Site experience of reinforced concrete construction desirable. Apply, stating age, qualifications, full details of experience and names of past employers, to Box 4703, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. Reinforced concrete senior and junior designer-detailers required for consulting engineer's office in Victoria. Opportunity will be given to visit sites whenever possible. Apply in writing giving particulars of experience or telephone Vigilant 5611 after 7 p.m. James E. Wardropper, 50 Belgrave Road, London, S.W.1.

SITUATIONS VACANT. Detailers experienced in reinforced concrete required for professional office. The work is varied, comprising all types of construction in concrete and steel, and offers scope for those interested in gaining design experience. Permanent positions with excellent prospects. Five-days' week. Apply, stating full experience, to Farmer and Dark, Romney House, Tufton Street, London, S.W.1.

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